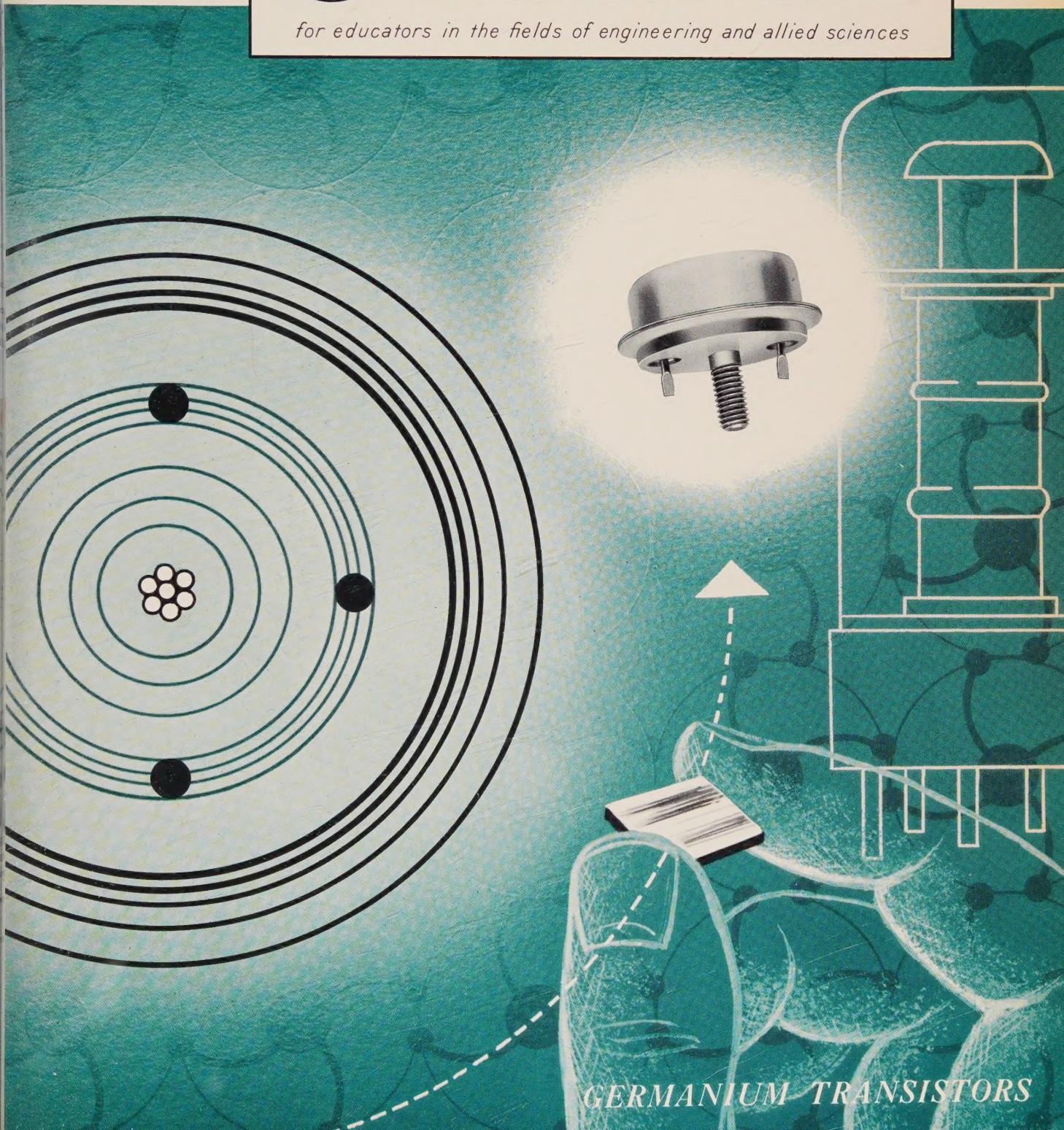


GENERAL MOTORS  
**ENGINEERING**

INDEX  
ISSUE

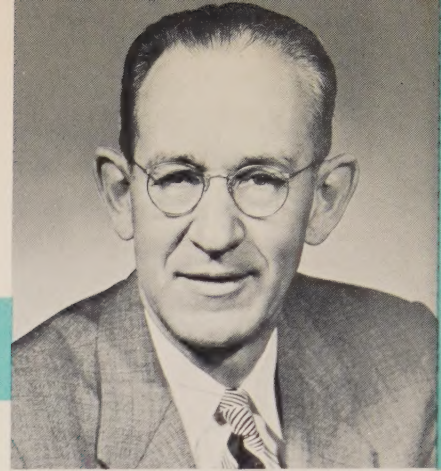
Volume 4    October-November-December 1957    Number 4  
**JOURNAL**

*for educators in the fields of engineering and allied sciences*



GERMANIUM TRANSISTORS

## Imagination—Key to Achievement\*



THE KEENEST tool in an engineer's kit is his imagination. This is the tool without which no great engineering or scientific accomplishment is ever consummated. Imagination—the only picture you can draw of the future. Imagination—that characteristic which is beyond other human capabilities. Imagination—the first and greatest ingredient in all creative effort.

Certain elements in the equipment of a useful person are not as necessary today as they were in earlier years. For example, in former decades, a man's capacity to produce sheer power was important, but not so today, because an electric motor can furnish power to better advantage than can man. Similarly, a modern encyclopedia represents a more comprehensive accumulation of knowledge than is possible within one human mind. And today's calculating machines are far more competent in certain mathematical areas than is a person. However, one of the essential elements for which no book or mechanism can possibly substitute is man's imagination.

The development and manufacture of aircraft and their propulsion have been erected more on imagination than on any

other factor. The visions of the Wright brothers were revolutionary, but not more so than the progress in aviation which has been made since their first flight half a century ago. For each step in this progress there was substantially no precedent, and guidance came only through imagination.

A modern example of imagination at work in the aircraft industry is found in the development of gas turbine engines. One of the more complex problems is the determination of the necessary characteristics of the fuel control system. To solve this problem, imaginative young engineers have used analog computers instead of engaging in costly and time consuming experimentation involving complete engines. In fact, before an engine is ever built, imagination permits applying the engine's characteristics to a series of "black boxes," and quickly obtaining substantially all necessary information through the analog.

There are, of course, other characteristics besides imagination which are necessary in a truly successful engineering life. Some of these are integrity, knowledge, dedication, persistence, courage, soundness of judgment and a love for

plain hard work. But imagination is the key that will open closed doors which otherwise would bar the engineer's progress.

Let us recognize a basic truth. Success in life is not a destination, it is a journey. Fortunately, this means that no one is obliged to work toward a single distant goal and be judged successful only if he attains that one objective. As with a traveler, the end of the journey is usually beyond the range of vision, but there is much of interest and beauty along the way to reward each day's steps. The happiest journey is not made with downcast eyes which see only tired, dusty feet. It is made with uplifted sight to appreciate the visible panorama and with the imagination to understand its significance and to picture what may lie beyond. The stars were made for those who look up and whose imagination knows no limitations.

A stylized, handwritten signature of Edward B. Newill.

Edward B. Newill,  
Vice President  
of General Motors,  
General Manager of  
Allison Division

\*Excerpts from the commencement address by Edward B. Newill, at Georgia Institute of Technology, June 8, 1957. Copies of the complete address may be obtained upon request.



### THE COVER

The transistor is a near-magic device, employing the principle of control of electrons in a solid rather than in a gas, as does the vacuum tube it replaces. This issue's cover, designed by artist Richard Renius, features a symbolic atomic structure with a background of atoms arranged in a crystal structure showing eight

electrons in each "outer ring," four controlled by each atom nucleus. The heart of the Delco Radio Division transistor pictured is a thin crystal of germanium, the solid semiconductor which makes possible the control of large amounts of power and the elimination of large, less reliable vacuum tubes.

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# GENERAL MOTORS ENGINEERING JOURNAL

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# How Fundamentals are Applied to the Design of Safe, Efficient Automotive Steering Systems

The basic design of automotive steering systems has not changed since the first cars were built, that is, the front wheels are turned individually permitting a four-corner, stable support for the vehicle at all times. The basic parts of the system in the early cars are essentially the same today: pivoted front wheels, a steering linkage, a steering gear, and a steering wheel for driver control. Improvements in the steering system, therefore, have consisted of (a) perfecting the components, (b) using improved materials and (c) redesigning system components to accommodate other evolutionary improvements made in the overall car design. To operate safely and efficiently, the automotive steering system depends upon the application of certain fundamentals of geometry and kinematics. The engineer must begin with the application of these fundamentals before he moves ahead with improvements of today's steering systems.

THE purpose of a steering system is to guide a vehicle safely on its course with a minimum effort on the part of the driver. In so doing, it should not cause undue wear of the tires or other parts of the system. It should be free of irritating vibrations but should reflect the effect of the road on the car to warn the driver before loss of control could occur.

Since the basic parts of the steering system—pivoted front wheels, a steering linkage, a steering gear and steering wheel—were present on the earliest vehicles, it is evident that the improved steering of modern cars must result from perfected elements. And indeed, the glossary of terms related to the steering system indicates that long studies have been made. A description of these terms will serve to show the detail with which the steering system is approached.

Camber angle, caster angle, toe-in, king pin angle, and scrub radius define the relation of the front wheel to its pivot on the vehicle (Fig. 1).

The *camber angle* is the outward tilt of the plane of the front wheel measured upward from the ground. If the top of the wheel were farther inboard than the bottom, the camber angle would be *negative*.

The *caster angle* is the tilt of the front wheel pivot upward and rearward as viewed from the side of the vehicle. When the pivot is disposed with a rake similar to a ship's smokestacks, the caster angle is positive.

The *king pin angle* is the tilt of the pivot downward and outward as viewed from the front.

The *scrub radius* is the distance from the king pin center to the center of the tire measured on the ground; the term *scrub radius* is not universal; *king pin radius* and *king pin at ground* also describe this dimension.

*Toe-in* is a measurement of the amount by which the distance between the rear-most portions of the front tires exceeds the distance between the foremost portions. In actual practice, toe-in measurements are usually made between the forward and rearward flanks of the tires.

Modern vehicles have a very small amount of toe-in and camber. Since the

king pin angle makes it necessary to raise the vehicle to steer it away from the straight-ahead position, a large king pin angle results in higher steering effort, faster return to the straight-ahead, and more stable handling.

The caster angle may be designed to add to or subtract from the tendency of the front wheels to return to the straight-ahead position. Many modern vehicles have negative caster angles.

The scrub radius causes the resistance to rolling of the front wheels to impart a compressive force to the steering linkage. This tends to minimize the effect of minor unbalanced masses in the front wheels. However, it provides a lever arm through which forces against the front

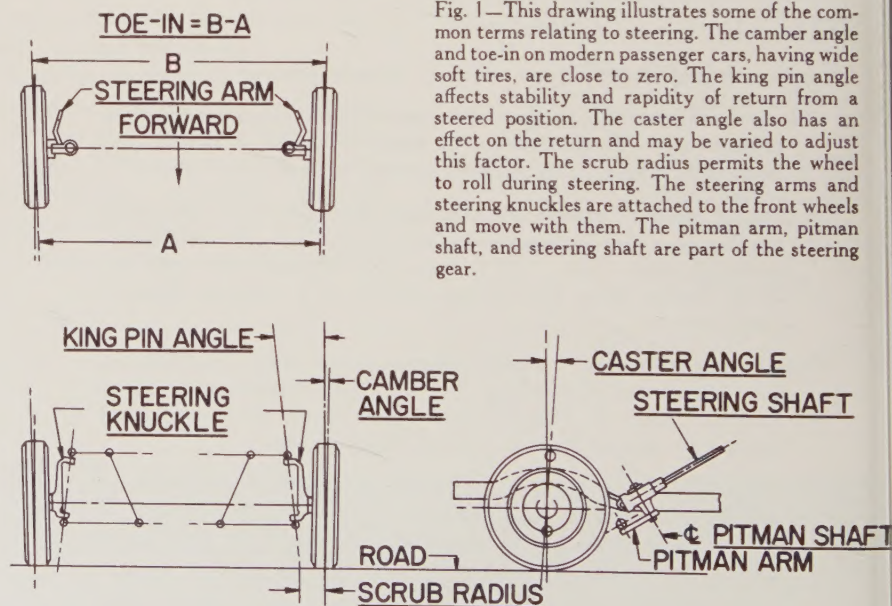


Fig. 1—This drawing illustrates some of the common terms relating to steering. The camber angle and toe-in on modern passenger cars, having wide soft tires, are close to zero. The king pin angle affects stability and rapidity of return from a steered position. The caster angle also has an effect on the return and may be varied to adjust this factor. The scrub radius permits the wheel to roll during steering. The steering arms and steering knuckles are attached to the front wheels and move with them. The pitman arm, pitman shaft, and steering shaft are part of the steering gear.

By DONALD P. MARQUIS  
Saginaw Steering Gear  
Division

Engineering design of the  
steering system starts  
with a problem in geometry

wheels react into the steering system.

*Ackermann* is the tendency of the front wheels to follow a correct non-scuffing pattern which, during steering, as a rule, is improved by adhering to the *Ackermann Layout*.

The *steering arms*, or plain arms, are the levers by which the steering linkage controls the front wheels. These arms generally protrude to the rear of the steering knuckle and aim inward at an angle defined by the *Ackermann Layout*.

The *steering knuckle* is the structural member which actually pivots the front wheel when steering occurs; it is usually integral with the spindle on which the wheel turns.

The *drag link* is the steering link con-

necting the pitman arm directly to another lever in the steering linkage.

The *pitman arm* is the lever through which forces from the steering gear are imparted to the steering linkage.

The *pitman shaft*, or cross shaft, is the output shaft of the steering gear; it is attached to the pitman arm.

The *steering shaft* is the input shaft to the steering gear on which the steering wheel is mounted.

The *gear ratio* is the fraction which measures the relative angular motion of the steering shaft to the pitman shaft.

The *overall ratio* measures the relative angular motion of the steering shaft to the mean rotation of the front wheel spindle.

the specific angle of the arms is made as a result of a graphical study often referred to as an *Ackermann Layout*. This selection is made by studying the position of the front wheels at various angles of steer with a selected steering arm angle, on a layout (Fig. 3). The layout demonstrates whether the direction of the outer wheel corresponds to the inner wheel and whether at a particular angle the tendency is to steer more sharply or less sharply, that is, whether the vehicle will tend to oversteer or understeer.

Designing the steering system must go hand in hand with the design of the suspension system of the vehicle. Very often, a different design of the suspension system or its components requires a new arrange-

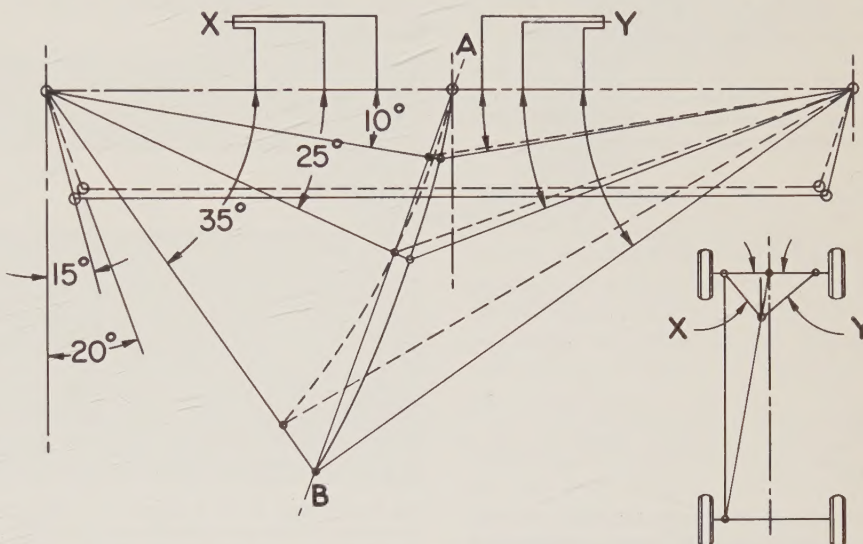


Fig. 3—The angular relationships shown in Fig. 2 cannot be laid out on an ordinary drafting board in a size large enough for accurate measurement of steering geometry. For convenience, therefore, the designer uses the layout shown in the lower right corner in which the angles  $X$  and  $Y$  are the same magnitude as angles  $X$  and  $Y$  in Fig. 2. This relationship is constructed in a much larger view as shown at the top left. This view compares the effect of  $15^\circ$  (solid line) and  $20^\circ$  (dotted line) steering arms on the deflection of the front wheels. The deflection of the outer wheel during a turn, angle  $Y$ , is plotted for assumed deflections of the inner wheel, angle  $X$ . In this case, comparisons are shown for inner wheel deflections of  $10^\circ$ ,  $25^\circ$ , and  $35^\circ$ ; normally, the study is made at  $5^\circ$  intervals. Intersections of the lines describing angles  $X$  and  $Y$  form curves, as shown, for the  $15^\circ$  steering arm (solid curve) and for the  $20^\circ$  steering arm (dotted curve). These curves are known as steering-error curves since their deviation from the line  $AB$  indicates the error in steering angles. Deviation to the right of line  $AB$  indicates that the right wheel will turn at a sharper angle or will *oversteer* the left wheel. Thus, the designer can observe from this layout that a  $15^\circ$  steering arm angle will cause the right wheel to oversteer the left wheel through  $35^\circ$  of steer of the left wheel. Using a  $20^\circ$  steering arm angle, however, causes a very slight oversteer effect through only  $25^\circ$  of the left wheel steer. To minimize abrasion of rubber and to provide the best control, the steering arm angle is usually selected to give the closest relationship through the turning range which will commonly be used, or about  $25^\circ$  of steer of the inner wheel.

### Geometry of the Steering and the Linkage Must be Studied First

A first consideration of the steering system designer is to have the two front wheels track correctly during a turn (Fig. 2). A close approximation of correct tracking is obtained by aiming steering arms in the general direction of the midpoint of the rear axle. The selection of

ment in the steering system to accomplish correct steering. Thus, the designer needs to be familiar with suspension problems and their effect on steering problems. For example, a special problem arises when it is impossible to connect the wheels by a linkage mounted to the rear of the wheel spindles. In order to maintain the relative angular relationship, the steering

Fig. 2—The ideal steering condition of a vehicle is represented in the above layout. Lines drawn through the front wheel spindles should intersect at a point on a third line extending the axis of the rear wheels. It is actually impossible to turn a vehicle without some scuffing of tires; however, manipulation of the angular relationships  $X$  and  $Y$  indicated in the sketch above develops the optimum condition. The angle of the steering arms with respect to the car centerline determines the wheel positions during a turn. Selection of this steering arm angle is made by studying a graphical layout.

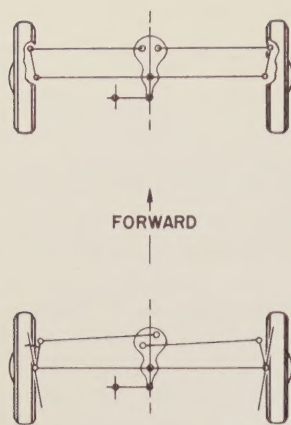


Fig. 4—Another arrangement of steering arms is necessary when the suspension design makes it impossible to project the steering arms rearward at a location behind the wheel spindles. A basic design in which the steering arms are positioned ahead of the wheel spindles is shown at the top. It also is probable, however, that the brake elements of the wheel make it impossible to use a steering arm in this position. The designer then moves the arms inward and compensates for this change in the location and movement of the inner ends of the tie rod, as shown below.

arms must protrude forward of the axle.

The desired steering arm angle is sometimes hard to obtain practically because of the interference of the brake elements on the front wheels. When this occurs, the designer usually attempts to adjust any compromise he makes in steering arm angle by applying a correction at the inner end of the tie rod (Fig. 4).

Many types of linkage were used during the years 1934 to 1950. Presently, the majority of American vehicles use only

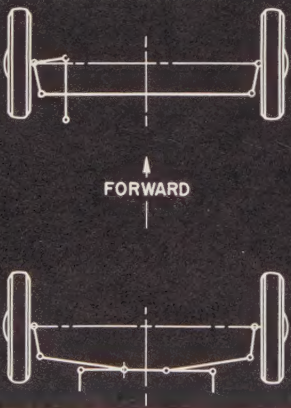


Fig. 5—Two basic types of steering linkage are in use on most American vehicles today. The simple combination of the fore-and-aft drag link and plain cross tie-rod, shown at the top, is used on many trucks. Passenger car systems, accommodating independent front suspensions, use a *parallelogram* linkage such as the one shown below. The pitman arm has a counter part idler arm on the opposite side of the frame and the outer ends of the two arms are connected by a cross rod. Separate tie-rods transmit the motion from this cross rod to the two steering arms.

two general types of linkage: (a) the plain, cross tie-rod type for solid front axles and (b) the parallelogram type for independent front suspensions (Fig. 5).

It is important that the motion of the suspension does not cause a change in the linkage relationship, resulting in a tendency to steer. Control of the linkage relationship is achieved—in the case of a solid axle—by pinning the front leaf spring at the end which corresponds with the steering gear location, usually the rear (Fig. 6). The gear location is then manipulated to make the arc described by the axle coincide, as closely as possible, with the arc described by the outer end of the drag link. It is, of course, impossible to make this correction in any other position than straight-ahead steering.

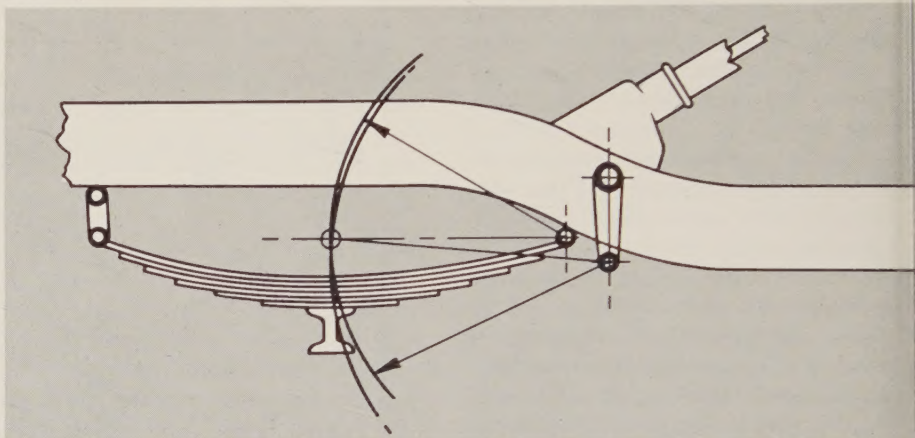


Fig. 6—A change in the position of the wheels due to bumps or other road conditions could cause a change in the linkage relationship resulting in a tendency to steer. To avoid this situation, the designer locates the drag link so that its outer end describes an arc that coincides as closely as possible with the arc described by the wheel movement. In the above arrangement showing a solid axle design, the leaf spring is pinned at the rear end to correspond with the steering gear location. Thus, both the axle and the end of the drag link oscillate about centers which are relatively close in the straight-ahead position.

A similar procedure is followed with the independent suspension (Fig. 7). When the suspension has been designed, arcs describing the motion of the suspension control arms are laid out. The steering-arm ball stud, attached to the steering knuckle, must follow a path defined by these arcs. The designer attempts to locate the inner end of the tie-rod at the center about which the steering-arm ball oscillates.

#### Steering Ratio Must be Selected

Another problem in achieving an efficient steering system is the design and improvement of the steering gear to give the necessary mechanical advantage for ease of steering.

As the weight of automobiles has increased and the tire inflation decreased,

it has been necessary to apply more and more effort to steer the front wheels. In cars having manual steering gears, this has resulted in the necessity for more efficient gears and for a higher mechanical advantage from steering wheel to steered wheel. The degree of mechanical advantage is referred to as the steering ratio or the *overall* steering ratio. Most of this effect is achieved in the steering gear, which ranges between 16 to 1 and 26 to 1 for American cars and is higher on commercial vehicles. This ratio may be constant throughout the range of steering or it may vary. The gears whose ratios vary are commonly arranged to have a relatively low numerical ratio for straight-ahead and a relatively higher figure in the steered positions.

The output of the gear is transmitted

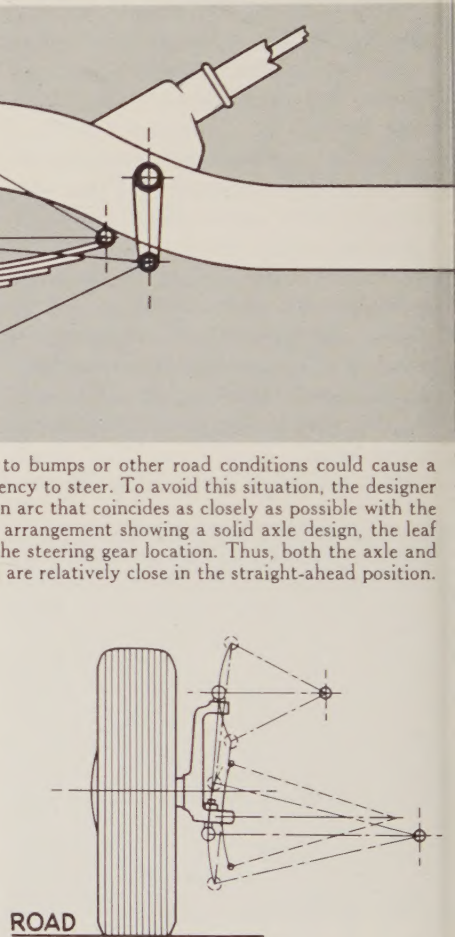


Fig. 7—A correction for suspension movement also is achieved in the case of independently suspended front wheels. The above diagram illustrates the method of locating the tie-rod so that the end of the tie-rod will describe an arc similar to the arc of the movement of the steering arm end. After the motion of the suspension control arms is determined, the arc described by the end of the steering arm is laid out. The tie-rod is then located so that its end oscillates in an arc which is as close as possible to the arc of the steering arm end.

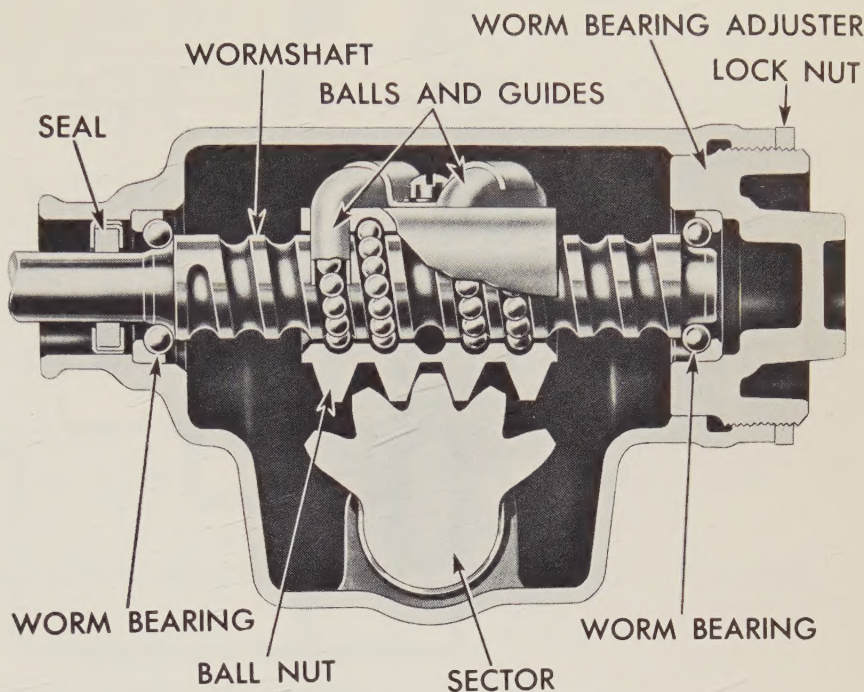
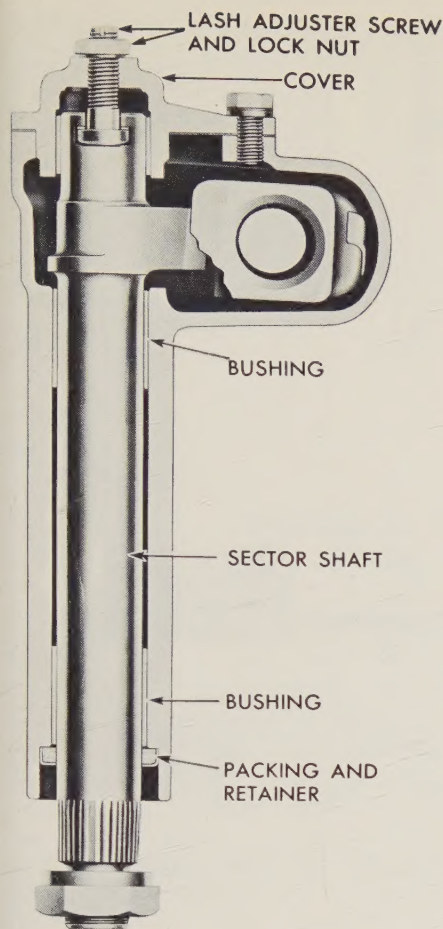


Fig. 8—The Saginaw recirculating ball nut gear is used on a large number of American vehicles today. It is basically a screw-nut type with recirculating balls between the thread grooves and the nut. This nut has rack teeth engaging with sector teeth on the pitman shaft. This gear provides increased efficiency to accommodate the increased steering demands caused by heavier vehicles and lower tire pressure.

to the steering linkage through the pitman arm and the motion is received from the linkage by the steering arms. Thus, if the pitman arm increases in length, the overall mechanical advantage of the system is decreased, that is, the ratio decreases. If the steering arms are increased in length, the ratio increases.

Most American automobiles are steered by means of a recirculating ball nut gear (Fig. 8). The ratio of this gear is determined from the following relationships:

$$K = \frac{M_I}{M_O}$$

where

$M_I$  = input motion to the gear pitch line

$M_O$  = output motion from the gear pitch line

$K$  = ratio of the steering gear.

$M_I$  and  $M_O$  are obtained as follows:

$$M_I = \frac{1}{L}$$

$$M_O = \frac{1}{2\pi R}$$

where

$L$  = thread lead

$R$  = pitch radius of sector

therefore:

$$K = \frac{2\pi R}{L}$$

This ratio is constant throughout the travel.

Another type of steering gear, the cam and roller gear, also has a constant gear ratio controlled by the following relationship:

$$K = \frac{2\pi R}{L}$$

A third type of steering gear, the cam and lever gear, varies in ratio depending on the varying effect of the variable lead on the cam.

The steering linkage causes the overall ratio to vary in various positions of steer which can be represented by a pattern of mechanical advantage (Fig. 9). The overall ratio is the product of the ratio introduced in the gear and that of the linkage. Very often, minor modifications in the

overall ratio are made by varying the linkage multiplication.

#### *Power Steering Permits Faster Turning and Combats Vibrations in the System*

The introduction of power steered vehicles began a reversal of the trend to higher ratios and a changing of the ratios on identical models for power and non-

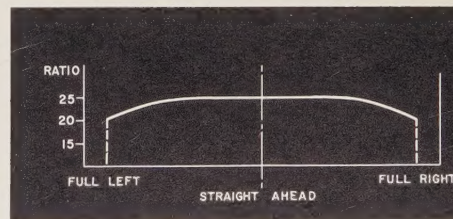


Fig. 9—This diagram shows a pattern of mechanical advantage for the overall ratio of the steering system. It demonstrates the change that occurs in overall ratio throughout the range of turning. The change in overall ratio is caused by changes in linkage relationships since the steering gear ratio remains constant throughout its travel. This information emphasizes the importance of proper linkage relationship, since the overall ratio is the measure of the actual mechanical advantage which the driver commands.

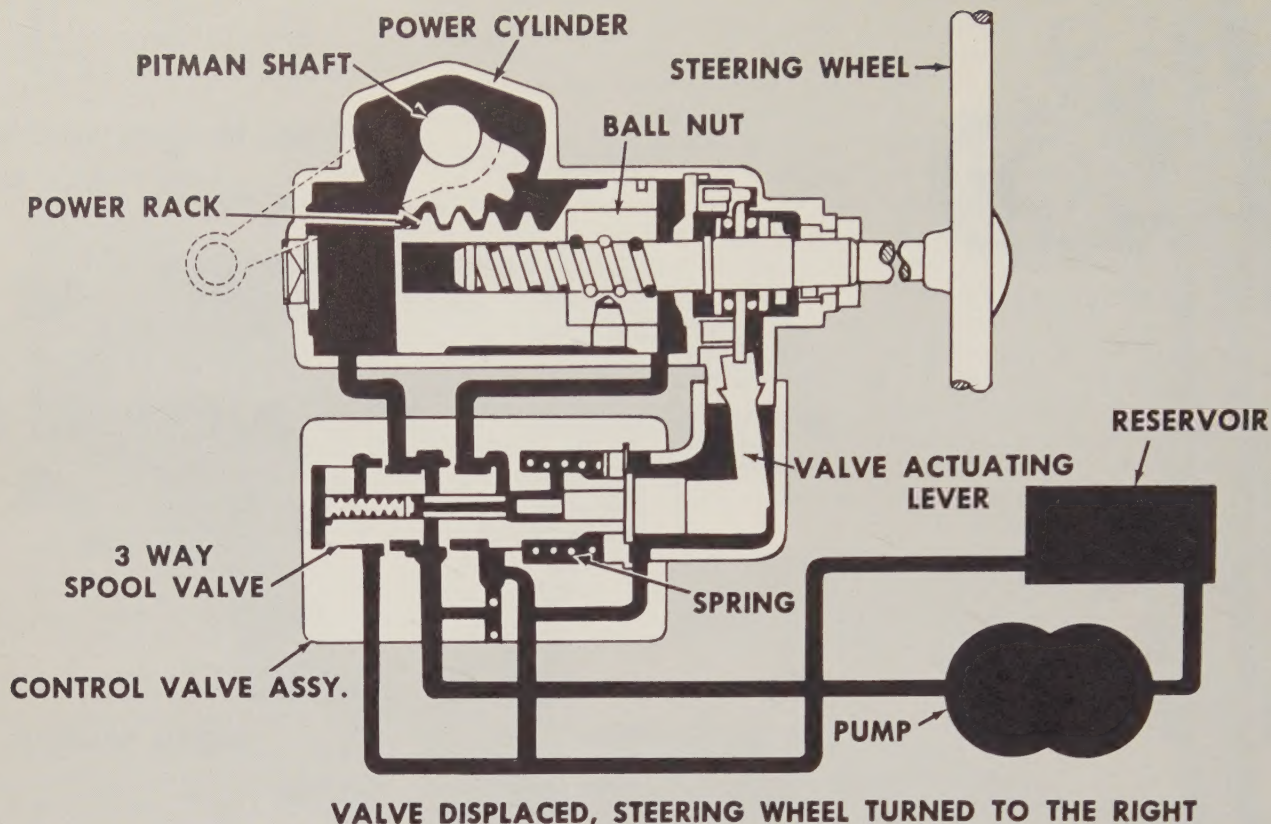


Fig. 10—Operation of the Saginaw power steering system unit is illustrated in the above diagram. It consists of a pump, an oil reservoir, a hydraulic valve which controls the flow of the oil, and a double-acting power cylinder and piston which apply the power to assist the steering system. The power cylinder is full of oil at all times and this oil acts as a cushion to absorb road shocks. A condition of a right turn steer is represented in the above arrangement of components. Due to turning resistance between the front wheels and the road, the steering worm tends to screw down into the ball nut. Therefore, as the driver applies right turn effort to the steering wheel, the worm moves forward (to the left) an imperceptible amount. This movement causes the valve actuating lever to move the valve spool backward (to the right), thus instantly affecting the flow of oil through the valve. High pressure oil then flows to the forward (left) side of the cylinder and moves the piston backward. As the piston moves, it moves the power rack with it, applying turning effort to the pitman shaft. The centering springs and the pressure from a valve reaction chamber tend to keep the valve spool centered. This means that the driver retains the normal "feel" of the road for he will need to apply continued effort to make an even greater turn or, conversely, the system will return to straight-ahead in the conventional way.

power steering. Thus, a typical 1957 automobile has a straight-ahead overall ratio with power steering of 20 to 1 compared to a ratio of 29 to 1 for its manual counterpart. The separation of these ratios has been approached cautiously by designers in order that the public can become accustomed to the faster steering possible with power.

The problem which has most persistently plagued the steering engineer has been that of unwanted vibrations in the steering system. The commonest of those, usually termed "wheel fight," results in a periodic rotation of the steering wheel in the driver's hands. The force for this vibration may originate in the front wheels from tire unbalance or out-of-roundness, from disturbance of the revolving mass of the front wheels (gyroscopic effect), or from steering error caused by error in the steering linkage

geometry. The force is encouraged to become a vibration by looseness in the steering system and by high efficiency of the steering system. It may be discouraged by maintaining snugness in the system. For example, the constant compressive pressure exerted on the linkage as a result of the frictional resistance in the front wheels acting through the lever of the scrub radius has generally been found more desirable than the balanced system (center point steering) which would result if the king pin centerline passed through the center of the tire contact pattern. Friction in the system damps the vibration and, in various models, friction has been added in the front wheel pivots (either king pin or ball joint) in the linkage and in the gear. It is obviously desirable to add the friction as close to the front wheels as possible. For many years, steering gears having high reverse

efficiency were undesirable for this reason.

Wheel fight also has been isolated by the introduction of flexible members in the linkage. This may take the form of springs in the linkage or rubber isolation in the pitman arm.

The remedies of isolation and damping usually are carefully engineered to avoid destroying the "feel" of the system—the reaction normally felt through the steering system as a result of forces acting on the front wheels. It is desirable that these forces be transmitted to the driver to serve as a warning against loss of control between tire and road.

The dash pot effect of power steering control (Fig. 10) is almost always adequate to overcome any force which tends to result in wheel fight. Even in the case of power steering, most cars permit the driver to sense the forces acting on the

front wheels. When these forces are light, the effect is achieved by springs holding the power steering valve in its centered position, thus maintaining manual contact with the road. For heavier forces, the result is accomplished by having the hydraulic oil act against the end of the valve so that it is necessary for the driver to overcome manually a fixed fraction of the road force. During the heaviest steering loads, such as standstill parking, this reaction force may prove a burden to the driver. Recent improvements have permitted the release of the reacting oil under such loads.

#### *Locating the Gear on the Vehicle can be a Problem*

Since 1934 the driver's position has moved further forward on the vehicle. As a result, the fitting of the steering system within the vehicle has become increasingly complex. The pattern of the steering linkage (and booster power cylinder) motion must be accommodated to the rear of the engine oil sump. The steering gear must fit into the transverse space between the extreme left turn position of the left tire and the farthest left position of the engine as it rocks on its mounts. Frequently, the widest portions of the gear are mounted over the frame or are imbedded in impressions in the frame. As a rule, the dimensional requirements of integral power gears are greater than manual gears, and great ingenuity has been exercised in designing the elements of these gears to provide minimum transverse width. The position in space above the gear is often occupied by the brake mechanism, making it undesirable to have a high gear. If the gear is extended lengthwise along the steering column, it becomes impossible to mount the gear shift mechanism on the steering column. It thus has been necessary to combine the power and manual elements allowing the oil to act in the chamber which contains the gear mechanism.

If the power is provided by adding a valve and hydraulic cylinder to the linkage, the clearance problem in the region of the gear is simplified. However, clearance problems in the area of the oil pan, clutch housing and suspension arms are intensified.

The power steering pump is customarily mounted on the forward portion of the engine and is belt driven by the water pump pulley. Space requirements (plus simplicity of mounting) have brought

about an alternate location on the rear of the generator, despite the undesirable high rotational speeds.

#### *Design Always Must Satisfy Safety Requirements*

Throughout all phases of the design, safety in the steering system is the paramount requirement. Alloy steels, for example, are specified in the critical elements of gear and linkage and are heat treated in the lower ranges of hardness to secure toughness under shock loading. The arrangement of king pin and caster angles, which causes a vehicle to return to a straight-ahead position, is zealously maintained so that friction in the system never prevents return. This is particularly important in power steered cars, since the oil must be ejected through the return circuits as the straight-ahead position is re-established. Most designs maintain a low *locking angle* in the linkage at full steer to prevent the combinations of starting friction and low mechanical advantage from causing a lock.

To avoid erratic conditions of steering even after many miles of service, the system is protected by wear compensating devices. Ball joints and pivots in the suspension and linkage are loaded either from the weight of the vehicle or by springs to maintain centers in spite of wear. The working elements in the steering gears are similarly pre-loaded in the straight-ahead position. These moving elements are commonly carburized and hardened on the operating surfaces to prolong wear.

#### *Final Design Step is Testing*

Before the steering system design is fully approved, it is subjected to a thorough testing program. Durability tests for steering gears fall into two classes: (a) tests for wear and (b) tests for fatigue strength.

The wear tests are performed in the process of car durability tests usually of 25,000 to 50,000-mile duration over a prescribed terrain having an effect on the car somewhat more destructive than average driving. In the laboratory, machines cycle the steering gears through full steer conditions for 30,000 cycles at about one-half parking load for manual gears and full parking load for power gears.

The fatigue strength tests are carried out by driving the car from 5,000 to 10,000 miles on the Belgian block road at

the GM Proving Ground. Frequently, these tests are arranged so that the steering system must have no failed elements after a mileage considerably greater than that required of other vehicle parts. In the laboratory, the gears are subjected to a rapid (900 rpm) cyclic loading 500,000 times, which is approximately equivalent to the maximum Belgian block loading.

Similar tests are performed on linkages. The laboratory wear test of the linkage usually requires the application of muddy water, since these parts are exposed to a considerable hydraulic pressure from water splashed by the front wheels. The steering gear, linkage, and suspension elements are also laboratory tested for impact strength and are required to have "tough" failures (breaks which show the metal bent due to overloading before complete separation occurred) to insure strength under occasional heavy shock loads and to discriminate between failures which cause accidents and those that result from road accidents.

#### *Conclusion*

While modern steering systems still consist of the elements present in early automobiles, their design has advanced over the years to permit great improvement of performance in effort, accuracy, wear, safety and ease of containment. The engineer has continued to apply the fundamentals of geometry and kinematics to obtain the proper steering function. When evolutionary changes in automobile weight, styling, and suspension designs introduced new problems to the steering system, the engineer kept pace with power assistance, new linkage arrangements, improved steering gears, and improved materials. Modern steering systems truly fulfill the visions of the automotive pioneer depicting fingertip control.

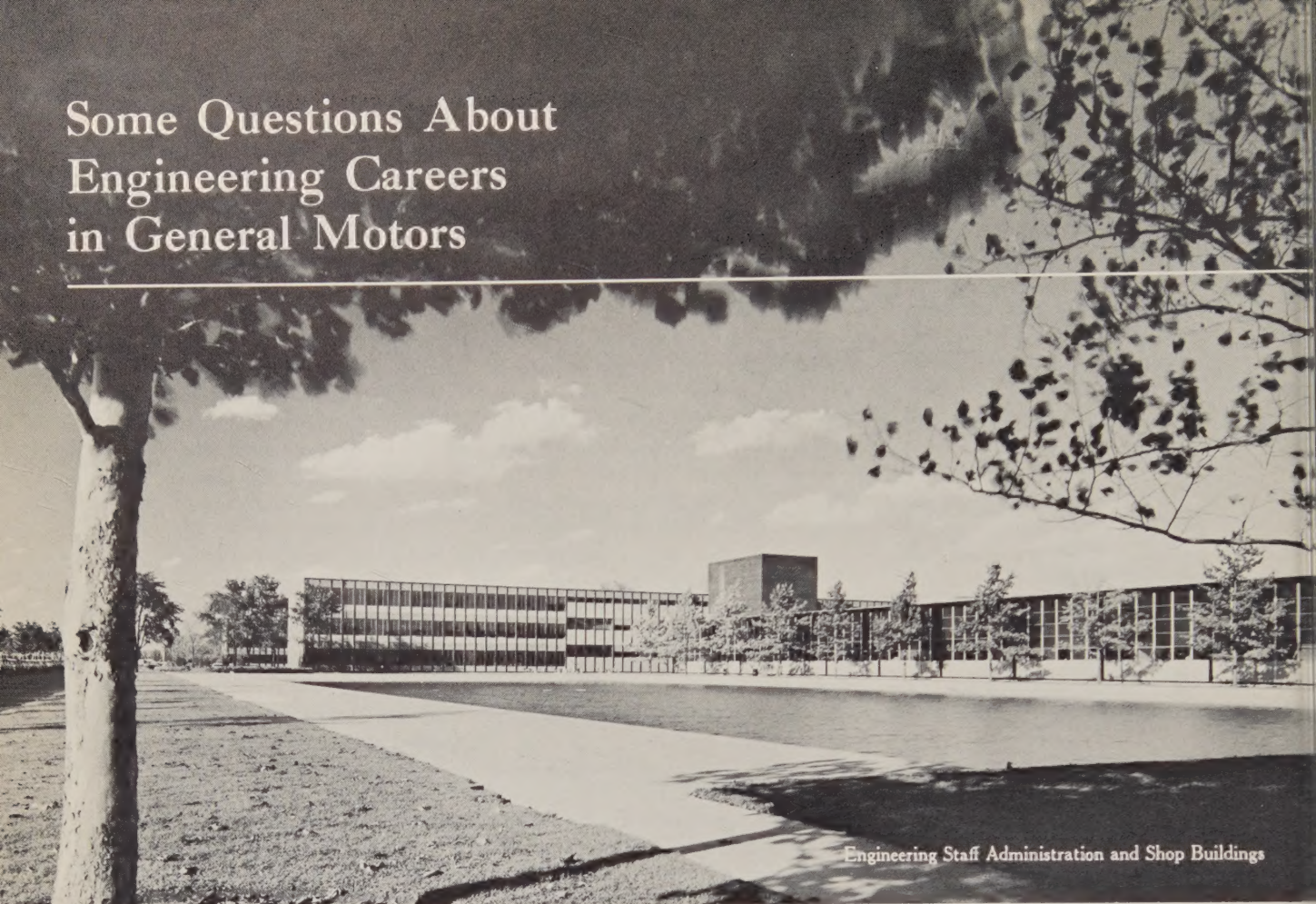
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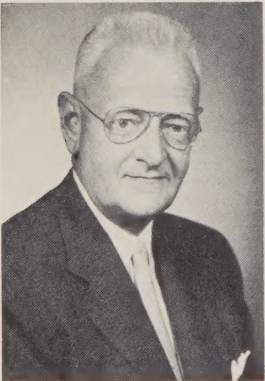
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# Some Questions About Engineering Careers in General Motors



Engineering Staff Administration and Shop Buildings



Whenever engineering students and General Motors people discuss careers with General Motors, certain fundamental questions are asked regularly by the students. They are concerned with such matters as training programs, personal advancement, professional recognition, and how engineering work differs in the various GM organizations. For the information of interested students, as well as others concerned with career planning, these questions have been summarized and answers given by Charles A. Chayne, Vice President of General Motors in charge of the Engineering Staff.

**Q:** *Just how does the engineer fit into the GM organization, Mr. Chayne?*

**A:** Engineers are the backbone of General Motors. Because we are an industrial organization dealing in the development and production of automobiles, trucks, household appliances, Diesel engines, aircraft power plants, and electrical products, among others, we look to our engineers for the technical knowledge necessary to design, test, and produce this

varied equipment. In addition to product and production activities, engineering skill is a fundamental and very important ingredient in the plant engineering, manufacturing, and research activities of GM.

If one thing can be singled out as basic to the success of GM over the years, and of utmost importance to our future success, I would say it is our people. Nineteen fifty-eight marks General Motors' 50th anniversary, but the combined education of our engineers totals many

thousands of years of technical knowledge and experience. We constantly are seeking qualified, young graduate engineers and scientists to join this team, to contribute their ideas and talents to the engineering organization as they learn from their associates and gain valuable experience.

**Q:** *In an organization the size of General Motors, what safeguard is there against the engineer getting "lost"?*

**A:** I think I can best answer this by saying that General Motors is an organization made up of separate Divisions. Each Division is under the direction of a general manager who, like the head of any company, is responsible for its successful operation. Each operating Division has its own engineering organization which is responsible for the product engineering of that Division (Fig. 1). The Central Office technical Staffs on the other hand are free to conduct independent studies and they also are available to assist the Divisions when needed.

A look at GM's engineering activities and the opportunities for young engineers

Furthermore, policy formulation in General Motors is separate from administration. Engineering policy, specifically, is determined by recommendations of the Engineering Policy Group of the General Motors Administration Committee.

Looking at the decentralized picture of General Motors, I feel that the college graduate enjoys a unique employment opportunity. The delegation of responsibility and our decentralization eliminates the effect as well as the feeling of bigness in our engineering organizations. These conditions permit each engineering group to operate effectively in the same manner as a well organized and efficient engineering department of a well managed small business, with the added advantage of support and facilities of a large corporation. It is particularly advantageous to our engineering personnel to work as several small teams rather than one large team. Each team and the personnel that comprise it not only function more effectively, but they are in a far better position to be recognized. As our engineers establish themselves importantly in any of our engineering groups it places them in the excellent position of being sought for more responsible positions on other teams.

It is not uncommon in General Motors for engineers who exhibit exceptional qualifications to move about in the overall engineering organization.

Our decentralized organization very definitely eliminates dead-ends and permits us to effectively use, recognize, and promote our personnel.

**Q:** You mentioned that GM engineering work is done both by the Divisions and by the Central Office. How is a Divisional engineering department organized?

**A:** There are differences in the engineering organizations of each Division, since each is tailored to the needs of the particular operation. A look at one of the car Divisions will give an idea of the organization of an engineering depart-

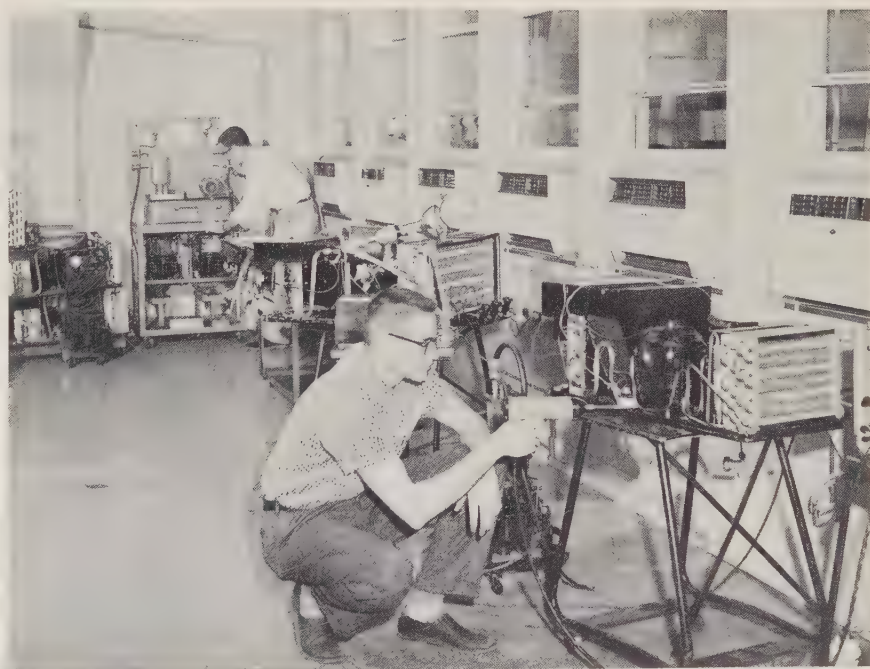
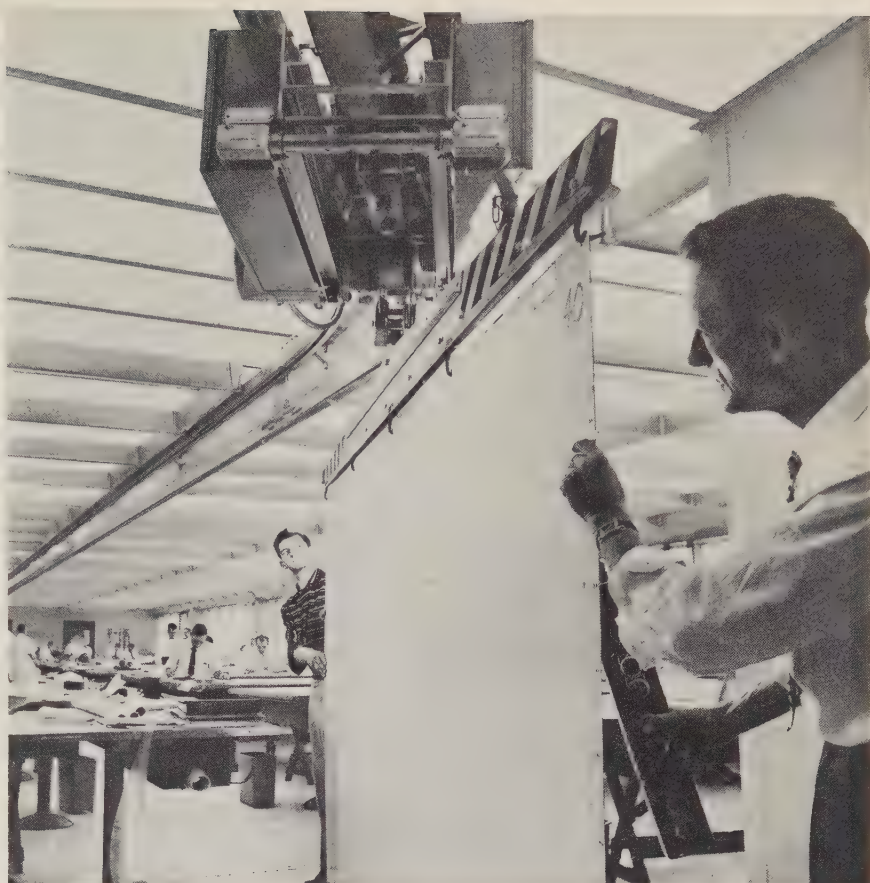


Fig. 1—Each General Motors Division designs, develops, manufactures, and merchandises its own products. The activities of two typical Divisional engineering Departments are represented above. In automotive design, aluminum plates—sometimes as large as 5 ft by 20 ft—are used for master drawings to insure dimensional stability. The plates receive eight coats of paint to provide a proper surface for the drawing. The draftsman and the designer work together as a part of the overall team effort necessary to develop a new product. A drafting area at the Chevrolet Engineering Center (Warren, Michigan) is shown at the top. At Frigidaire Division (Dayton, Ohio) a new laboratory facility recently has been completed to aid in the development of appliances and refrigeration equipment. The view at the bottom shows a section of the laboratory devoted to work on room air conditioners.

# CHEVROLET ENGINEERING ORGANIZATION

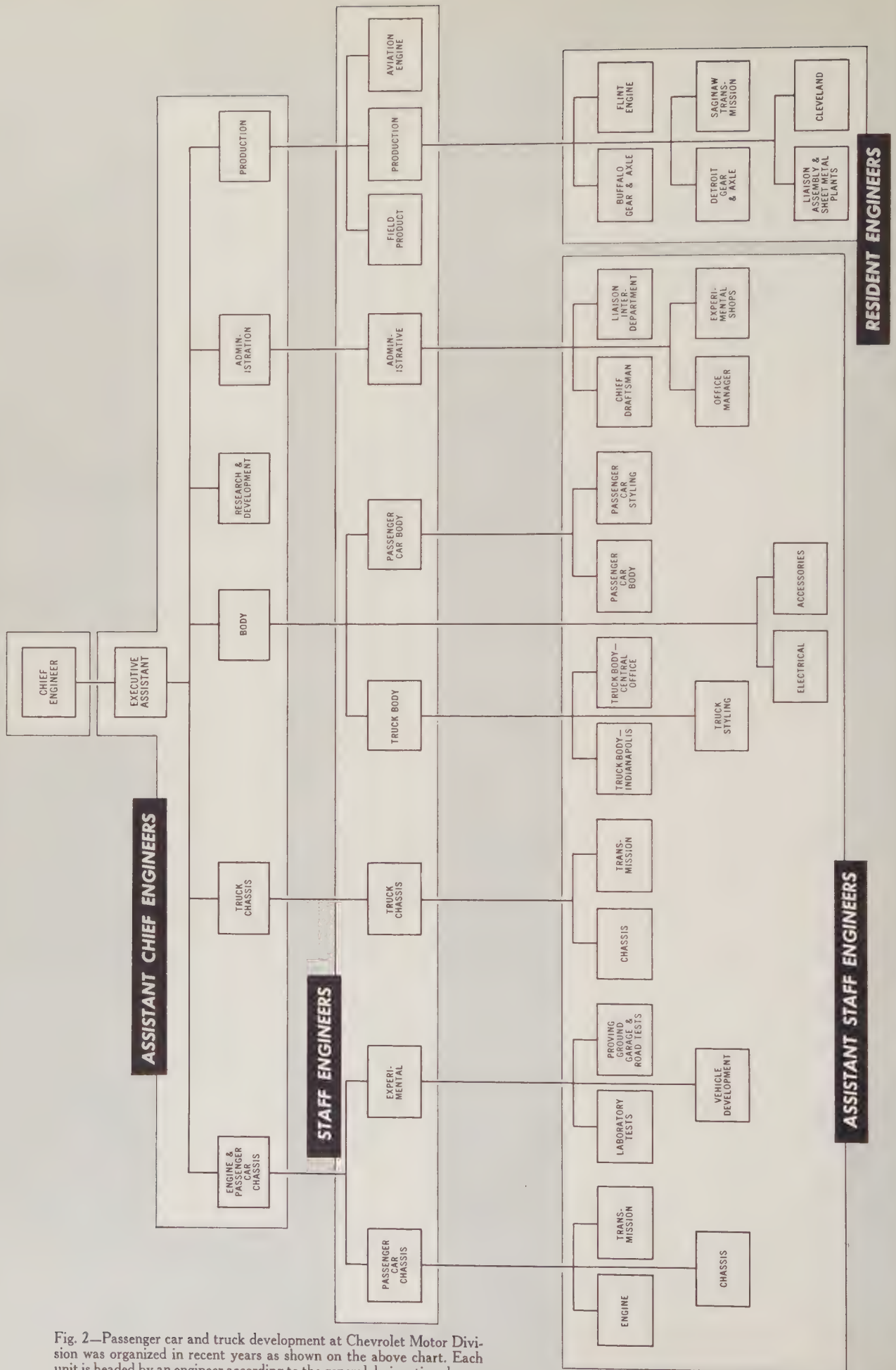


Fig. 2—Passenger car and truck development at Chevrolet Motor Division was organized in recent years as shown on the above chart. Each unit is headed by an engineer according to the general designation shown, for example: staff engineer.

ment, as well as some of the typical varieties of work conducted within such an organization. Here is the way the engineering department of Chevrolet Motor Division was organized in recent years.

Four levels of authority are responsible for the success of the Chevrolet Engineering Department programs: the chief engineer, assistant chief engineers, staff engineers, and assistant staff engineers (Fig. 2). The assistant chief engineers may have charge of more than one section, and each section is, in turn, divided into several groups. For instance, the assistant chief engineer in charge of engine and passenger car chassis supervises the Passenger Car Chassis and the Experimental Sections. In the Passenger Car Chassis Section, the Engine Group is responsible for the design of all components for passenger car and truck engines. The Transmission Group is responsible for the design of both standard and automatic passenger car transmission; and the Chassis Group is responsible for the design of the frame, the front and rear suspension, the steering control, the rear axle, and all other chassis items. In the Experimental Section, the Laboratory Tests Group conducts various kinds of tests on any part or assembly of either a passenger car or truck from simple endurance tests of components to full-scale dynamometer engine and transmission tests. The Proving Ground Garage and Road Test Groups are available to handle Chevrolet's tests conducted at the General Motors Proving Grounds. Engineers of the Vehicle Development Group work on special projects usually dealing with the vehicle as a whole, such as sound and vibrational analysis. They are concerned particularly with problems which do not show up under separate tests of engine, transmission, or chassis, but appear when components are assembled.

The Truck Chassis Section and Body Section, each headed by an assistant chief engineer, are organized in a similar manner according to the principal phases of design and development.

The Research and Development Section conducts studies leading to the development of new and advanced vehicle designs, such as the chassis design for the Chevrolet Corvette, and perfects these designs to the point where they may be turned over to the Production Design Group.

The Administration Section provides

services necessary to the work of the whole Department and is responsible for the interpretation and execution of company policies within the Engineering Department. This section also provides drafting services; machine facilities for experimental fabrication and assembly of designs prior to testing; maintenance of engineering records, specifications, and parts lists; and liaison with other Chevrolet Departments, such as Sales, Advertising, and Public Relations.

The Production Engineering Section is concerned with quality control. Resident engineers at the manufacturing plants maintain contact between the design engineering and production people so that designs of all parts are suitable for Chevrolet's production schedule and are not unnecessarily difficult to make or assemble. The Field Product Section investigates Chevrolet Service Department reports of difficulties in the field.

*Q: How are the Central Office technical Staffs set up, Mr. Chayne, and what do they do?*

*A:* The Central Office technical Staffs concerned with product development have the responsibility of conducting long-range developmental programs on products of interest to General Motors as a whole as well as assisting the Divisions on their own engineering programs whenever asked. However, we recognize that the primary engineering responsibility in General Motors is with the Divisions producing the products.

A Division is free to conduct all of the research and engineering involved in the manufacture of its products if it so elects. Each Division has its own engineering facilities tailored to its own needs. At the same time that work is being done on the Division's annual new model development, projects are under way which may not reach production for several years. This work may be done by the Divisions or by one of the Central Office Staffs. While the Divisions are free to work on long-range developmental programs, usually their engineering work load entailed in the design of new models for the immediate years ahead prevents them from reaching too far into the future. Consequently, the Divisions frequently prefer to have long-range developmental work done in the Central Office rather than use their own engineering personnel which may be fully occupied with their immediate new model programs. At the

start of any long-range developmental program it is usually not known what Division or Divisions might use the product. Often a development proves to be of greater importance to another Division than the one originating a program.

These Central Office Staffs concerned with developmental work are located at the General Motors Technical Center, a 330-acre site north of Detroit. They are identified as the Research Staff, Styling Staff, Engineering Staff, and Process Development Staff.

The Research Staff is the oldest of the Central Office Staff developmental groups. Although the engineers of the Research Staff, generally speaking, do not take part in a Division's new model development, they do contribute a great deal to General Motors engineering progress. Research Staff personnel are primarily concerned with fundamental long range studies likely to benefit a majority of the Divisions, since the Divisions usually must concentrate on projects which show possibilities of immediate commercial application. Such basic information is essential to long term technical progress, for today's science is tomorrow's engineering, and the next day's production. Perhaps equally important, however, is the combination of specialized research personnel and facilities available to the Divisions for assistance on especially knotty service and developmental problems. Some of the important developments in which Research Staff personnel have participated are tetraethyl lead, Freon, lacquer finishes, modern Diesel engines, improved bearing materials, high temperature alloys, and high compression engines.

The Styling Staff is, of course, responsible for the appearance of all General Motors products that meet the public eye, and it works very closely with the Divisions on new model styling. Separate studios are maintained for each car Division, for Chevrolet Trucks, for GMC Trucks and Coaches, for Electro-Motive locomotives, for Euclid earth-moving machinery, and for Frigidaire appliances. In the studios the designs are developed first on paper, then in three-dimensional, full size clay models. In the fabrication shops prototype models are built, using plaster, plastics, glass fiber, wood, and metal. An entire section is devoted to the design of automobile interiors. Engineers, stylists, color experts, plaster and plastic craftsmen, wood and metal model makers,

trimmers, painters, and administrative people comprise this important team.

The Engineering Staff is made up of a number of semi-independent groups, some of which perform specific services for the benefit of General Motors as a whole and others which carry on developmental work in the area between the long-range work of the Research Staff and the more immediate problems of the Divisions' engineering departments.

Some of the corporation-wide activities handled by the service groups are patents, engineering standards, proving grounds, vehicle safety, and photographic and reproduction work. Engineering development is carried on by four other groups: Vehicle Development, Suspension Development, Transmission Development, and Power Development. The Engineering Staff relies upon the Engineering Policy Group for the establishment of broad policies with regard to its activities. Therefore, the primary responsibility of the developmental groups is in connection with projects deemed to be of importance to General Motors as a whole. However, the Engineering Staff has in the past assisted the engineering departments of the Divisions in basic engineering studies as well as carrying on independent developmental projects. Among them are such engineering developments as automatic transmissions, fuel injection, air suspension, dynamic wheel hop absorbers, independent front suspension, the axial flow compressor, and others.

The Process Development Staff originated in 1946, and is much younger than the other Central Office developmental activities. While the Research, Styling, and Engineering Staffs deal with product development, the activities of this Staff, broadly speaking, are concentrated on:

- (a) the development of the best method for the production of new products
- (b) the improvement in quality of products already in production
- (c) the elimination of undesirable or unsafe working conditions
- (d) the reduction in cost of the product involved . . . or any combination of these objectives.

The developmental work of this Staff is performed principally by three Sections: (a) the Production Engineering Section, (b) the Work Standards and Methods Engineering Section, and (c) the Process Development Section. The

first two Sections listed work primarily through committees composed of GM engineers from the various operating Divisions and coordinated by Staff engineers. The Process Development Section has modern laboratory and shop facilities for development of mechanical, electronic, and hydraulic equipment and for chemical and metallurgical studies affecting manufacturing.

**Q:** *What are the opportunities of working at the General Motors Technical Center?*

**A:** The Technical Center Staffs seek promising engineering graduates each year much the same as the Divisions. The Engineering Staff, for example, hired 13 graduates in 1957. Of course, there are a greater number of employment opportunities among the Divisions. Thus, if the graduating engineer considers the General Motors organization as a whole, he may be able to determine better just what job and location best suits his qualifications and interests. The opportunities for contribution to the engineering profession through one's work and rewards from it

are the same throughout General Motors, so the question of investigating one or more Divisions or Staffs of GM should be based on the job openings available at the time, the type of work in which the individual is interested, and his qualifications for a particular position.

**Q:** *In an organization engaged in such diversified operations as you have mentioned, how is the engineering graduate placed on the job which best suits his interests and abilities?*

**A:** Two of the basic operating principles of General Motors are to put the right person in the right job and to train him for the job to be done.

The newly employed graduate reports to the personnel department of his GM unit for orientation and assignment to a thorough training program. The training program is designed to enable management to work closely with the new employee to help him determine further where his interests and abilities lie and in which field his progress will be the greatest. During this training period, the graduate may work in several key depart-

## TYPICAL COLLEGE GRADUATE ENGINEER TRAINING PROGRAM

### For Project Engineers—One Year

<b>I</b>	<b>General Orientation Period</b> . . . . .	<b>2 weeks</b>
<b>II</b>	<b>Specific Work Assignments in Project Engineering</b> . . . . .	<b>16 weeks</b>
<b>III</b>	<b>Work Assignments in Related Departments</b> . . . . .	<b>26 weeks</b>
	Motor Engineering	10 weeks
	Axle and Transmission Engineering	8 weeks
	Drafting (Product)	8 weeks
<b>IV</b>	<b>Other Department Work</b> . . . . .	<b>8 weeks</b>
	Personnel	2 weeks
	Finance	1 week
	Manufacturing	3 weeks
	Purchasing	1 week
	Sales	1 week

Table I—A variety of assignments is arranged for the graduating engineer who joins a GM car manufacturing Division. A typical training program for project engineers is outlined above.

ments where he is given the opportunity to utilize both his technical and non-technical knowledge (Fig. 3). At the end of the training period, a particular job assignment is recommended which will be advantageous to both General Motors and the employee. From then on the employee's progress is dependent on his ability, his work performance, and his attitude and cooperation in working with his fellow employees as part of the GM team.

A typical training program for a college graduate engineer entering a project engineering activity in a car manufacturing Division is outlined in Table I.

**Q:** *What are the opportunities for personal advancement within GM for the engineer?*

**A:** I would say they are unusually good. We are aware that engineers value the opportunity for professional recognition both inside and outside of the organization where they work. General Motors encourages its engineers to participate in technical society activities. Most of the Divisions have periodic technical meetings at which engineers present papers and exchange information on their work. GM engineers also are active in speaking before civic organizations and on college campuses. Additional schooling and advanced education is encouraged. Any number of our Divisions and the Staff groups have varied plans whereby the engineer can take advanced training.

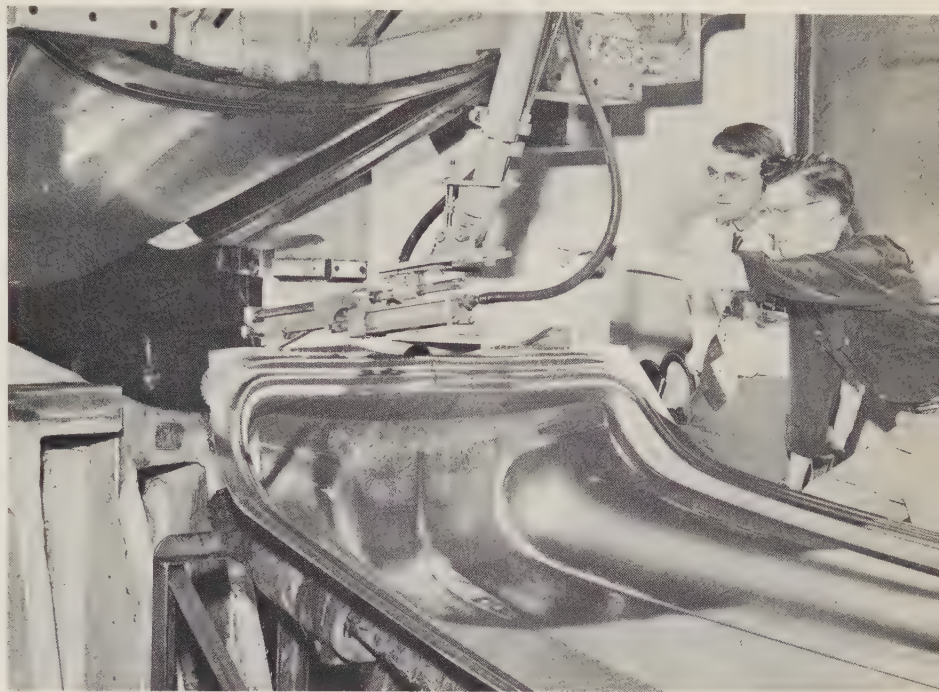
Relative to promotions on the job, General Motors endeavors to promote qualified individuals from within the organization when openings occur, rather than seeking to fill positions with individuals from outside of GM. Thus, as openings occur, GM engineers are constantly moving up to positions of greater responsibility which, by reason of ability and experience, they are prepared to fill successfully. In addition, some Divisions have a new salary classification for senior engineers on the managerial level though not engaged in managerial work. This classification is designed to reward those engineers who are more valuable working in their technical specialty than in administrative positions and who do not desire an administrative type job. It is an alternate route to that of administrative positions, giving equal prestige, authority, and privileges in the professional field.

There also is a policy of transfers from Division to Division within GM which encourages another operation to employ

an individual should an opening arise which represents a promotion for him.

I might add that engineers with ability and willingness to work have fared well in General Motors and have risen to positions of Corporation-wide responsibility and leadership. We engineers are particularly proud of the large proportion of

for technological progress which have been opened in recent years: atomic energy and all its applications, chemical and metallurgical developments, the gas turbine engine for automotive use, new forms of power, improved methods of processing, and advanced types of products.



**Fig. 3—**The young engineer's education does not stop with the receipt of his degree. After he is employed, he receives specific on-the-job training to prepare him to use most advantageously the fundamental technical knowledge he has learned in the classroom. In the above illustration, a manufacturing operation at Buick Motor Division (Flint, Michigan) is studied by a young engineer with the assistance of an experienced engineer.

General Motors management coming from the engineering organization and every effort is made to be ready at all times with replacements for those who are advanced.

Each year of late General Motors has been hiring about 1,000 new engineering graduates to provide replacements for those who retire and, more importantly, for those who are promoted to other positions. These engineering graduates are in addition to the 300 to 350 graduates coming from our own General Motors Institute.

**Q:** *Mr. Chayne, in your opinion, what lies ahead for the engineering profession and for industry?*

**A:** The future looks good for engineering and engineers, for industry in general and General Motors in particular. Consider for a moment a few of the vast fields

American industry is doing a praiseworthy job in keeping up with and adding to our technological economy. With our population growing at a rate never before experienced, a greater market demand is apparent already. Industry must continue not only to improve its products but to produce more and more of them.

Engineers are playing a vital role in carrying on this technological progress. It is their job to enable industry to meet the increasing demands of its customers and, in turn, continue to advance our American standard of living through new and improved products.

In my lifetime I have seen the engineering profession establish itself among the foremost of those groups benefiting mankind. The engineer is a leader in our economy today—and he is indispensable to our progress and productivity in the future.

# Electrical Engineers Develop a New Concept for Multi-Path, Direct Current Armature Windings



By WILLIAM E. MENZIES  
Delco  
Products  
Division

For many years two basic types of armature windings for direct current machines have been used—the lap and the wave. Although armatures employing these two basic types of windings, or modified versions of them, have performed satisfactorily there has always been the challenge to develop a new type of winding which would be free of certain limitations and undesirable characteristics associated with them. Recently, Delco Products Division engineers developed such an armature winding—a multi-plex wave winding which eliminates undesirable equalizing currents and heating losses. The result has been a winding affording a great degree of flexibility in application to d-c armature design.

**A**N IMPORTANT step in the overall design of a direct current machine is the design of the armature with its component conductors. The voltage developed, current carrying capacity, kilowatt or horsepower output, and speed are directly dependent on the proper design and operation of the armature. The number of armature conductors and the number of parallel paths through the armature constitute primary design considerations and have a direct bearing on the type of armature winding to be used.

Two basic types of armature windings are used today—the lap, or parallel, winding and the wave, or series, winding. In addition, there are other windings which represent modifications or adaptations of these two basic types. Because of certain inherent characteristics and limitations related to armature windings, the designer must keep in mind basic fundamentals of electrical engineering when specifying the type of winding to be used for a particular application.

Lap and wave windings have been used for quite some time and thousands of d-c machines have been built using these windings. Electrical machine designers have always felt, however, that along with improvements made in other

d-c machine components and operating controls something could be done with the armature winding to further improve its efficiency in contributing to the generation of electrical energy. Such a step was recently taken with the development of a new type of d-c armature winding. Before describing this new type of winding, however, it is desirable to review some of the fundamentals of windings and to list the various limitations and characteristics which gave rise to the need for developing the new type of winding.

## *Equalizer Connections Provide Potential Equalization in Lap Wound Armature*

In the design of an armature for a d-c machine of a given size, voltage, and speed, the use of a two-circuit wave winding with single-turn coils may result in too few commutator bars for good commutation. In this case, it is customary to use a lap winding with equalizer connections. These connections join in parallel coils lying in corresponding positions under different poles of the same magnetic polarity. If the poles do not have the same magnetic strength, circulating currents will flow at any load in both the equalizer connections and the armature winding to bring the poles to approx-

A balanced network multi-plex wave winding free of equalizing currents

imately the same magnetic strength. If equalizer connections were not used, voltages at brush arms of like polarity would vary with the strength of the poles and would cause equalizing currents to flow in both the brush arm connectors and brushes with attendant sparking. By using equalizer connections those commutator bars which are under brush arms of like polarity are tied together electrically at any instant, thus providing a path within the armature for the flow of the equalizing currents. Because of the heating produced, equalizing currents are undesirable. They are unavoidable, however, if potential equalization and good commutation with a lap winding is to be secured.

## *Equalizer Connections Not Needed with Wave Wound Armature*

With the wave type of armature winding the potential at the brush arms is a composite of the potential generated by those conductors lying under all poles. Because of this, equalizer connections are not necessary. Furthermore, the individual coils of the wave winding assure equal potentials under the brush arms. This is due to the coils being so disposed that they connect portions of the commutator which are spaced approximately the span of the brush arms of like polarity.

Fig. 1—Shown on page 15 is a polar diagram (a) for a multi-plex wave winding developed by Delco Products Division engineers for use on d-c machines. The particular diagram shown is for a four-pole, wave wound, duplex, singly re-entrant armature winding. The armature has nine slots, four coils per slot, and 36 coils and commutator bars. The interconnections, shown as lines within the commutator, connect alternate commutator bars to bars which are diametrically opposite. A developed diagram (b) shows the individual coils of the winding, together with their associated commutator bars. The two branches for the four parallel paths are disposed one above the other so that the commutator bars, which are normally at the same potential, are located directly above or below each other. The coil sides are given numbers corresponding to the number of the slots in which they lie. In the developed

diagram the interconnections appear as vertical lines connecting alternate pairs of commutator bars. It can be seen that in each case the interconnections join pairs of coils lying in the same slots. Since the interconnections are in voltage opposition in the network, there can be no appreciable current flow around the loops or in the entire winding under no-load conditions. For example, the interconnections joining the commutator bars 20 and 2 and 22 and 4 connect two coils with sides lying in slots 2 and 4 and slots 6 and 8 in parallel with two coils with sides lying in the same slots. It will be noted in this winding that each coil, through its associated interconnection, is connected between adjacent commutator bars (c) in the same manner as the coils in a lap winding. (d.) Thus, the voltage between adjacent bars is always that voltage associated with a single coil.



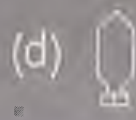
(a)



(b)



(c)



(d)

### *Combination Lap and Wave Wound Armature also Used on D-C Machines*

In addition to the basic lap and wave types of armature winding used for d-c machines, there is a combination lap and wave winding which has twice the customary conductors in each slot and, as usually arranged, has line voltage between each of the four-layer deep conductors in each slot. The wave winding occupies the first and fourth layer and the lap winding the second and third layers. Both windings are connected to the same commutator. The coils of the wave winding are a full complement of equalizers for the lap winding. Any magnetic unbalance causes equalizing currents to flow in both the wave and the lap windings.

### *Magnetic Unbalance Produces Flow of Equalizing Currents*

In the design of a magnet frame for a d-c machine, magnetic unbalance often is difficult to avoid. For example, consider the case where clearance is necessary for a shaft to which an armature is geared. Here, the required clearance makes this section of the frame considerably thinner than the rest of the frame, resulting in magnetic unbalance.

In variable speed and variable voltage machines, magnetic unbalance of a high order often is introduced purposely to improve stability. In this case, the use of an armature winding with equalizers would be practically ruled out.

If equalizers are used and if the brushes on any one brush arm wear down and lose contact with the commutator, the equalizers have to be of sufficient cross section to carry the normal current to this arm.

There is no appreciable value in having the poles of a d-c machine exactly equal in magnetic strength. Because equalizing currents associated with a lap winding cause additional heating losses, it is obvious that it would be desirable to have a winding where such currents would not be present, even with magnetic unbalance.

### *Multi-plex Windings Give Abnormal Commutation*

Electrical engineering text books present and discuss multi-plex windings—that is, lap or wave windings consisting of two or more single windings wound in parallel on the armature core—as a means of obtaining multiple paths. Not always mentioned, however, is that they

are generally regarded as unsatisfactory in practice.

Multi-plex windings are composed of a number of single or multiple re-entrant windings, or branches. Each winding, or branch, is associated with a succession of commutator bars proportionally interspread among the commutating bars of the other branches. The branches are paralleled only through the brush surface contact with their associated bars. After a period of operation the commutator bars associated with one branch become blackened, causing objectionable sparking. This condition usually becomes worse until there may be considerable sparking, even at no load.

### *New Type Armature Winding Developed to Meet Specific Need*

A multiple-path winding having the desirable characteristics of a wave winding and free of equalizing currents has long been a goal of electrical machine designers. It was with this thought in mind that Delco Products engineers set out to develop an armature winding which would have such features for use on the Delco line of d-c machines. The result has been a *balanced network* multi-plex wave winding (Fig. 1) free from the usual difficulties encountered with previously used multi-plex windings.

The balanced network d-c armature winding has the separate windings, or branches, paralleled internally. In the network thus formed, equalizing currents or magnetic equalization are non-existent. The internal paralleling consists of connecting certain equipotential points to obtain internal voltage balance and a definite potential relationship between adjacent commutator bars.

Commutating pole strengths are determined by the load current, external to the armature. It is obvious, therefore, that in armature windings having multiple paths the various paths should divide the load current equally for optimum commutation, since they are influenced by the same commutating pole fluxes. In the multi-plex wave winding under consideration, the interconnections assure a nearly uniform division of the load current among the various branches of the armature winding. Even if the division of load current at the brush surface is uneven between the commutator bars associated with the various branches of the winding, the paralleling junctions formed by the interconnections

cause the load current to divide in a nearly uniform manner among the branches.

The interconnections are connected in parallel between the branches to carry jointly only that portion of the load current represented by the lack of uniform division at the brush surface. As a result, the current carried by each interconnection is small and the cross section needed for the interconnection is small. Actually, the size of the interconnection is usually determined by mechanical strength rather than electrical conductivity.

The balanced network multiple path armature winding has been applied to d-c machines having more than four poles. With this type of winding the number of parallel paths is not limited to the number of poles. Many six-pole machines having four parallel paths have been built. An eight-pole machine may have 4, 6, or 8 parallel paths. In fact, it is not entirely impractical to have the number of paths equal to twice the number of poles.

In a four-pole equalized lap winding only an even number of slots may be used. With the balanced network multi-plex wave winding it is not necessary to use a number of slots which is divisible by half the number of poles (Fig. 1). A greater degree of flexibility is available, therefore, than is afforded by a lap wound armature.

### *Summary*

The results achieved through the use of the balanced network wave winding indicate that:

- It has the desirable characteristics and advantages of the wave winding
- Unwanted equalizing currents and attendant heat losses associated with lap windings are eliminated
- The number of slots in the armature need not be divisible by half the number of poles and the number of parallel paths need not be limited to the number of poles, as is the case in a lap wound armature
- The interconnections may be of very small cross section, thereby requiring the minimum of space for easy attachment to the commutator bars. Even accidental removal of brushes from one brush arm will not increase appreciably the current flow in the interconnections
- The balanced network indicates no short circuiting when tested by a growler, a transformer device used for such purposes.

# GM "School" Trains Personnel in the Industrial Application of Radioisotopes



During the 10-week schooling period a student is shown how isotopes are produced and is informed about supply sources. Also, he is instructed in the measurement and monitoring of radioactive materials. Part of the school period also is devoted to instructing the students in the present day industrial application of radioisotopes (Fig. 1) and the possible ways to use them tomorrow. Laboratory assignments provide the students with an opportunity to use various pieces of specialized equipment required in radioisotope laboratory work. (Fig. 2).

Safety considerations are of prime importance and the student is thoroughly instructed in the safety precautions which must be taken when working with radioactive materials. He is briefed about government regulations applying to radioactive materials and is familiarized with educational problems. This provides the student the means for keeping his particular Division appraised of nuclear developments and the background for training personnel under his supervision in the care and safekeeping of isotopes.

The purpose of the school is to provide GM Divisions with qualified personnel trained in the safe use and application of radioisotopes. As more and more ways are discovered to use isotopes in manufacturing, engineering, and research GM Divisions will have qualified specialists available to supervise their application.

**D**URING the past few years the industrial use of radioactive isotopes has continually increased. More and more ways are being found to apply the radioisotope to industrial research, engineering development, manufacturing processes, and quality control.

To make full use of the isotope as an important and versatile industrial tool requires trained personnel familiar with the special problems involved in the application and handling of radioactive materials. To overcome a shortage of trained personnel in this particular area General Motors has started its own school for training men in the industrial uses of radioisotopes. Students for the school are engineers, chemists, and physicists from various GM Divisions.

The school presents an intensive 10-week course of study. The students begin with a two-week lecture and laboratory series at General Motors Institute. There they receive information on the basic physics and fundamentals of radioactivity. The students then move to the GM

Technical Center for eight weeks of lectures, experiments, and safety instructions.

The school at the Technical Center is conducted in the Isotope Laboratory, operated by the Physics and Instrumentation Department of the GM Research Staff. The students also make a field trip to Oak Ridge, Tennessee to see the graphite reactor and the swimming pool reactor. They also see the Atomic Energy Commission's radioisotope processing and distribution facilities, which supply most of the isotopes used in their experiments.

The faculty for the school is comprised of men from the Isotope Laboratory who obtained much of their basic education in handling "hot" materials from the Atomic Energy Commission. In 1953 the GM Research Staff began assigning specialists to Oak Ridge classes and several of the AEC-trained men were later transferred to the Isotope Laboratory organization. Other members of the organization were former A.E.C. employees. These men are engaged primarily in radioisotope research.

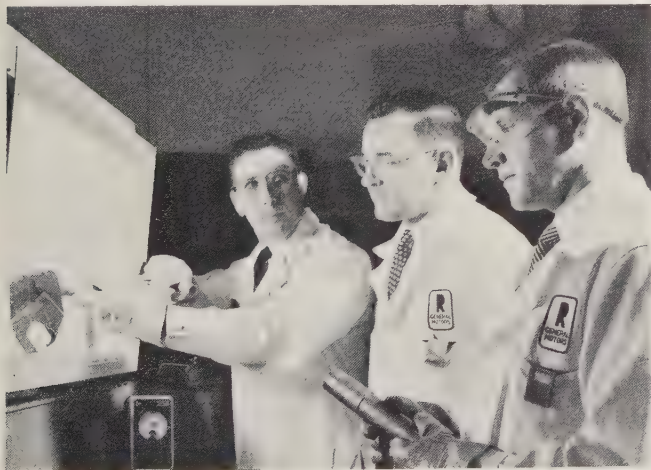


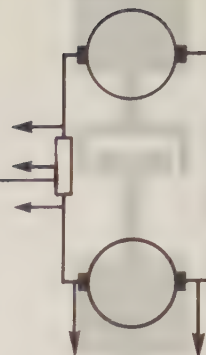
Fig. 1—During the training program conducted at the Isotope Laboratory of the GM Research Staff, students are instructed in present day industrial applications of radioisotopes. Shown here is an instructor withdrawing a tool loading fixture from the protective hood of a lathe on which radioactive cutting tool material is used under simulated production conditions. The student in the center is observing the operation while the student at the right prepares to insert a workpiece, part of an automotive transmission shaft, into the fixture. Shown in the pocket of the lab coats worn by the men is a dosimeter which must be worn by everyone entering the laboratory. The dosimeter measures any radiation dose, however slight. A complete exposure record is kept on all personnel coming in contact with radioactive materials.



Fig. 2—During laboratory assignments students become acquainted with various types of equipment used in radioisotope work and learn the techniques required for their operation. The student in the foreground is shown inserting a radioactive counting sample in a lead shielding "pig." In the background a student handles radioactive materials in a Berkeley box. This box, which has built-in rubber gloves and sleeves, is equipped with its own drain and air supply system and is specially designed to prevent the spread of radioactive materials which might interfere with sensitive measurements made in other parts of the laboratory. Shown between the lead shield and the Berkeley box is a counting instrument, standard equipment in radioisotope laboratories.

# A Discussion of Present Day Dynamometers: Their Application, Operation, and Control

Early methods for measuring the power output of a prime mover were based mainly on the use of friction and water brakes. Since that time much has been accomplished in the field of power measurement and control of engineering tests. The Prony brake and similar types of power absorption devices have been made obsolete by the electric dynamometer. Horsepower and speed ratings of prime movers have increased; accuracies of torque and speed measurements have improved; and interlock systems to protect both personnel and equipment have been developed. Programming methods to control automatically the operation of a dynamometer throughout a test cycle have increased greatly the flexibility and usefulness of the dynamometer, especially in the automotive industry. While the flexibility and accuracy of the dynamometer have increased, so has its complexity. An overall dynamometer facility utilizes mechanical, pneumatic, hydraulic, and electrical and electronic components. The engineers and skilled technicians who work together to assure proper dynamometer performance must be familiar with the various types of dynamometers available for use and their method of application. They also must be familiar with the instrumentation necessary for measuring speed and torque and the factors governing the satisfactory performance of a complete dynamometer facility.



THE electric dynamometer is not a new device. It has been used for quite some time to measure the power from or to a prime mover. It has only been in the past few years, however, that the dynamometer has developed into a highly valuable tool to make possible a wide variety of engineering tests under con-

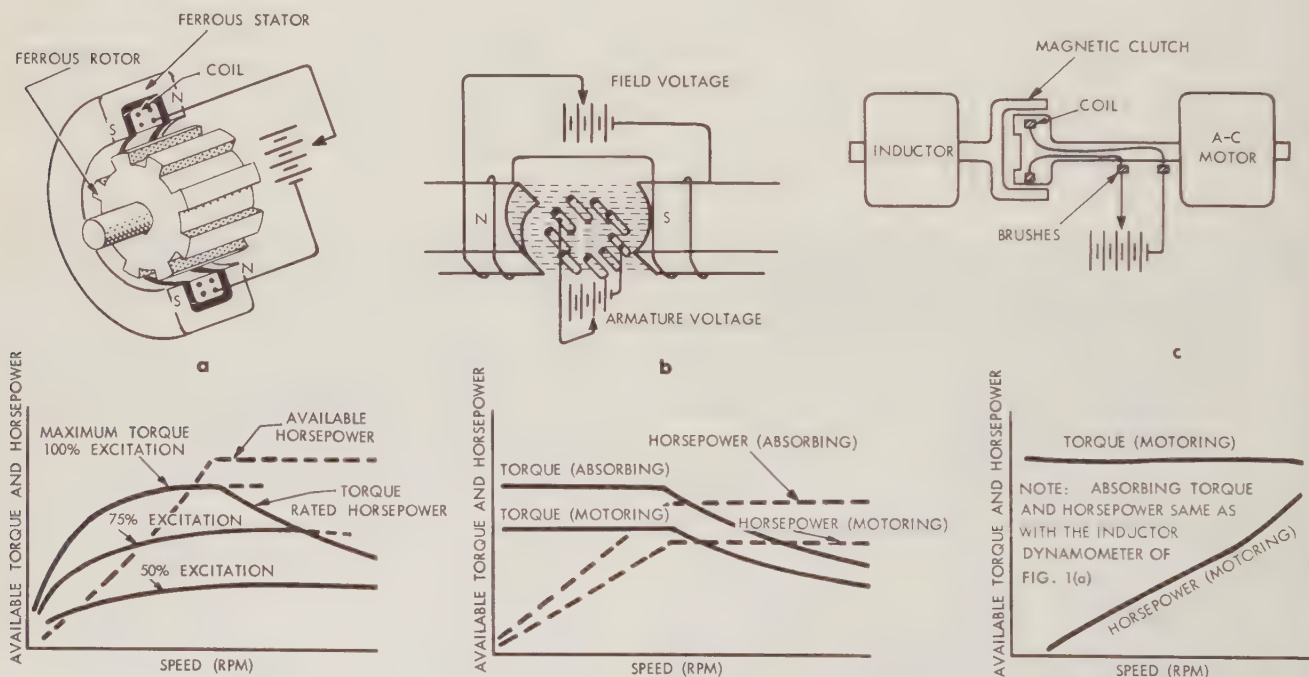


Fig. 1—Shown here are the three basic dynamometer designs together with their basic operating characteristics. The inductor, or eddy current brake, dynamometer (a) consists of a solid ferrous rotor with slots in the periphery. (Smooth rotors also are available for high speeds.) The rotor turns in a magnetic field produced by a d-c current in a coil wound inside a ferrous stator. Rotation produces a pulsating magnetic field in the rotor teeth, thereby inducing eddy currents. These induced currents develop a second magnetic field in the rotor teeth which reacts with the field in the stator, thereby producing torque. Power is absorbed as heat in the ferrous members and cooling is accomplished by flowing water. Torque and horsepower of the inductor dynamometer are limited by cooling ability and field voltage rating. The direct

current dynamometer (b) is a d-c motor with separately excited armature and field. It can absorb or deliver power. Torque is produced by reaction between two magnetic fields—one from the dynamometer field and the other developed by current in the armature conductors. With the d-c dynamometer, torque is limited by the cooling capacity of internally mounted fans and the speed is limited by the ability of the rotor components to stay together. The combination, or universal, dynamometer (c) consists essentially of an inductor and an a-c motor coupled to the same shaft through a magnetic clutch. When absorbing, the magnetic clutch is de-energized, disengaging the a-c motor shaft from the absorber. When motoring, the absorber field is turned off and the magnetic clutch energized to produce the desired control.

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Dynamometer usefulness  
increased by new instru-  
mentation techniques

trolled conditions. The application of precision instrumentation for measuring speed and torque, the use of programming methods for automatic control during a test cycle, and the development of interlock systems for both personnel safety and equipment protection have all served to increase greatly the flexibility, reliability, and accuracy of the dynamometer.

The General Motors Research Staff, located at the GM Technical Center, makes extensive use of approximately 50 dynamometers of various types for testing rotating shaft machinery. Dynamometers are used to determine torque and horsepower characteristics of engines, thereby facilitating new concept validation and incremental improvement detection. Transmission and rear axle efficiencies, under such duplicated road conditions as speed, torque, and oil temperature, are determined by dynamometer testing. Dynamometer controlled programming tests on automobile components aid in determining the suitability of special oils and lubricants. Outdoor road conditions of an automobile, such as speed, torque, temperature, wind, inertia, pressure, humidity, and sunlight, are duplicated repeatedly on chassis dynamometers located in the cold room and wind tunnel facilities of the Research Staff.

*Dynamometers May be Classified as  
to Their Function, Design, and  
Devices They Test*

The dynamometers available today (those which measure force and linear velocity will not be discussed) can be categorized as to the function they perform, their design and construction, and the types of devices they test.

The category of dynamometers in

regard to the function performed includes: (a) the absorber dynamometer, which absorbs power from the device being tested and (b) the motoring, or driving, dynamometer, which delivers rotative power to the device being tested.

Dynamometers categorized by design and construction include: (a) the inductor, or eddy current, dynamometer, (b) the direct current dynamometer, and (c) the combination, or universal, dynamometer (Fig. 1).

In addition to dynamometers being classified by the function they perform and their design and construction, they also are classified as to the devices they test. Included in this classification are the

engine dynamometer, transmission dynamometer, rear axle dynamometer, and chassis dynamometer (Fig. 2).

*Speed and Torque Measurements  
Must Be Accurate*

Horsepower is equal to speed times torque times a constant. It follows, then, that the accuracy of the calculated value for horsepower depends upon the accuracy of the speed and torque measurements taken during a test. Various types of instrumentation and methods are available for measuring speed and torque.

*Speed Measurement*

Instruments available for speed measurement include the stroboscope, hand speed indicator, frequency meter, continuous electric counter, d-c voltmeter-type tachometer, and electronic counter tachometer. The latter three are most commonly used (Fig. 3).

*Torque Measurement*

Speed can be measured to an accuracy of plus or minus one rpm or better. The limiting factor, therefore, in accurate horsepower determination is the measurement of torque. Dynamometer torque is measured by having the torque arm, attached to the cradled dynamometer stator, exert a force on some type of weighing system.

Trunnion, or cradle, bearings allow the stator of a dynamometer free, limited movement which permits the torque on the stator to be measured. The most important source of error in torque measurement is trunnion bearing friction. It is important, therefore, to minimize this source of error. Ball bearings do this to some extent, but an even better approach is to use oil-floated trunnion bearings (Fig. 4).

The next most important source of error in torque measurement is due to the torque from pedestal mounted accessories, such as a tachometer generator, by-passing the weighing system. (A tachometer generator, used in the speed control circuit, produces a d-c voltage proportional to speed). By cradle mounting such accessories, their torque absorption can be measured. Another source of torque leakage is through stiff electric cables. Also, cooling water pressure changes can effect torque accuracy. In this case, the cooling water piping should be so arranged as to direct the water toward the centerline of the dynamom-

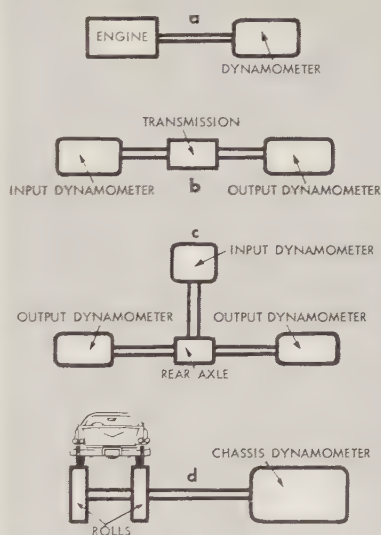


Fig. 2—Dynamometers also are named by the devices they test. Engine dynamometers (a) are used primarily to establish speed-torque and horsepower characteristics of rotating shaft machines. Any of the three basic dynamometer designs (Fig. 1) can be used to test internal combustion, free piston, and gas turbine engines; motors; or pumps. In fact, any machine having a rotating shaft can be coupled to the shaft of a dynamometer. Two dynamometers—one for motoring (input) and one for absorbing power (output)—are used to test a transmission design for its efficiency, life, output speed, torque, and slippage under various loads (b). Three dynamometers are used to conduct similar tests on rear axles (c). The chassis dynamometer, which is usually of the d-c design, tests the performance of the complete car under simulated road and environmental conditions (d). The test cell housing the chassis dynamometer can be a wind tunnel or a cold or hot room where temperature, humidity, wind velocity, light radiation, or other driving conditions can be duplicated.

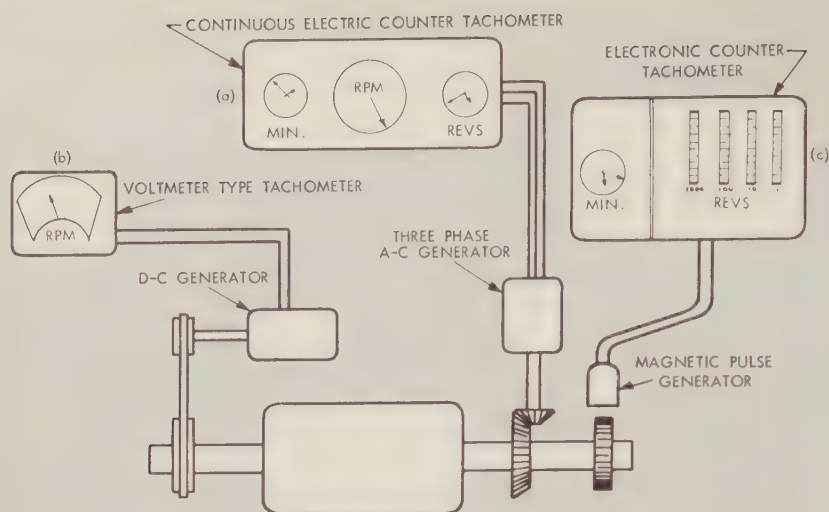


Fig. 3—The three most commonly used methods for measuring dynamometer speed are shown here connected to the same shaft for comparison. The continuous electric counter (a) consists of an eddy-current slip disc, or speedometer-type indicator, in addition to a revolution counter and a precision electric timer. The actuating device usually is a three-phase, a-c generator which sends its signal to the speed indicator and the revolution counter. The timer starts and stops the revolution counter either manually or automatically. Accuracies of plus or minus 10 rpm can be obtained when the tachometer is in good working condition. The d-c voltmeter tachometer (b) is the simplest method to use for speed measurement. The signal from a permanent magnet d-c generator, belted to the dynamometer shaft, is fed to a d-c voltmeter which can be calibrated directly in speed (rpm). Accuracies of plus or minus two percent of the indicator full scale reading can be obtained. The electronic counter (c) is a much more accurate speed measuring device. This device requires little maintenance and has the characteristic that its readings are either within plus or minus one count or otherwise are so far off as to be noted quickly. The actuating device consists of a pulse generator with its magnetic field interrupted by teeth on a gear or serrated cylinder attached or geared to the dynamometer shaft. An electronic counter totals these magnetic pulses for a predetermined unit of time, usually about one second, and displays the speed readings intermittently. Revolutions may be counted for any desired length of time by using the electronic counter in conjunction with a precision electric timer. To obtain continuous speed readings a d-c voltmeter, using an inexpensive meter movement, often is used with the electronic counter.

eter. Any forces due to pressure changes will then act at a zero torque arm and will not cause zero shift in the torque weighing system. (Zero shift refers to the movement of an instrument indicator an equal amount away from its correct value at all points on the scale.)

When the above factors affecting accurate torque measurement are reduced to negligible amounts, the remaining consideration is the accuracy of the torque weighing system. The weighing system used may be mechanical, pneumatic, hydraulic, or electric (Fig. 5).

#### Calibration of Torque Weighing System

Calibration of torque weighing systems can be made using standard weights correctable to grains and checking torque arm distances correct to plus or minus 0.002 in. Correctable accuracy then reduces to the ability of the weighing system to repeat its reading. Repeatability of 0.1 per cent full scale reading is not at all uncommon on dynamometer torque weighing systems. Accuracies to

within plus or minus 0.5 per cent or better full scale reading can be obtained.

#### Torque Measurements for Transmission Testing

Transmission efficiency testing requires torque measurements of high accuracy because efficiency calculations are based on the difference between two torque readings. For example, an error of plus or minus 0.5 lb-ft in both motoring and absorbing dynamometer torque measurements, when the torque difference is 10 lb-ft, can produce an efficiency calculation error of 10 per cent. For this reason, accuracies to within 0.2 lb-ft usually are required for this work. These requirements can be met and the entire torque range of the dynamometer covered by using either multiple-range weighing indicators or jug weights. (A jug weight is a weight added to the torque arm, at the proper side of the dynamometer, for the purpose of unloading the weighing system—that is, shifting zero—so that larger loads can be measured). These allow the

use of a dial of narrow span at selected points of operation.

The torque weighing system for a dynamometer used in transmission test work may have zero shifts due to temperature changes. For this reason, ambient air temperatures in a transmission dynamometer test cell should be maintained constant to within 1°F or 2°F. Torque weighing systems used with transmission dynamometers are taxed to their utmost and temperature changes may affect them in this work, where such changes would not be noticed on most other applications.

To check and adjust torque system zero shift, the torque weighing system is first unloaded and the dial then re-zeroed. The mechanical weighing system

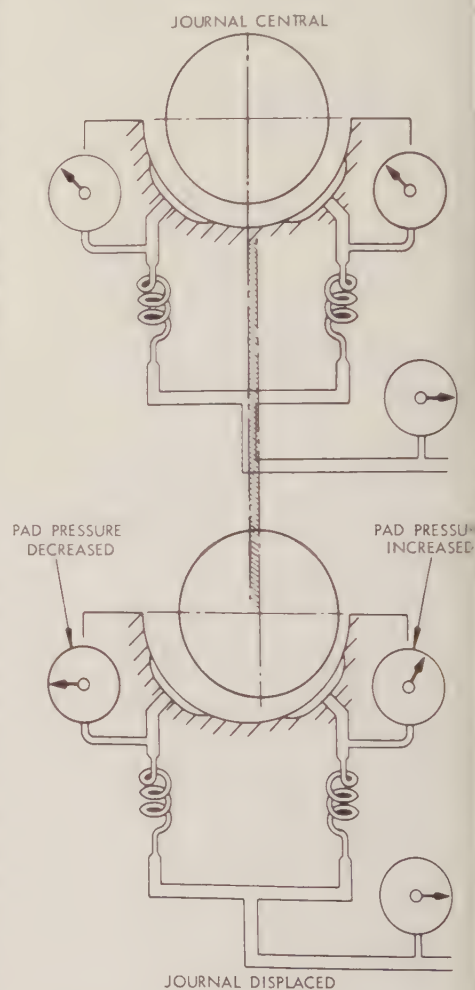


Fig. 4—Trunnion bearing friction is minimized considerably by the use of oil-floated dynamometer trunnion bearings. This diagram shows how oil pressure is increased on one side of the journal when it moves off center. The difference in oil pressures on the two sides forces the journal back to the central position. The oil-floated bearing is a GM Research Staff development.

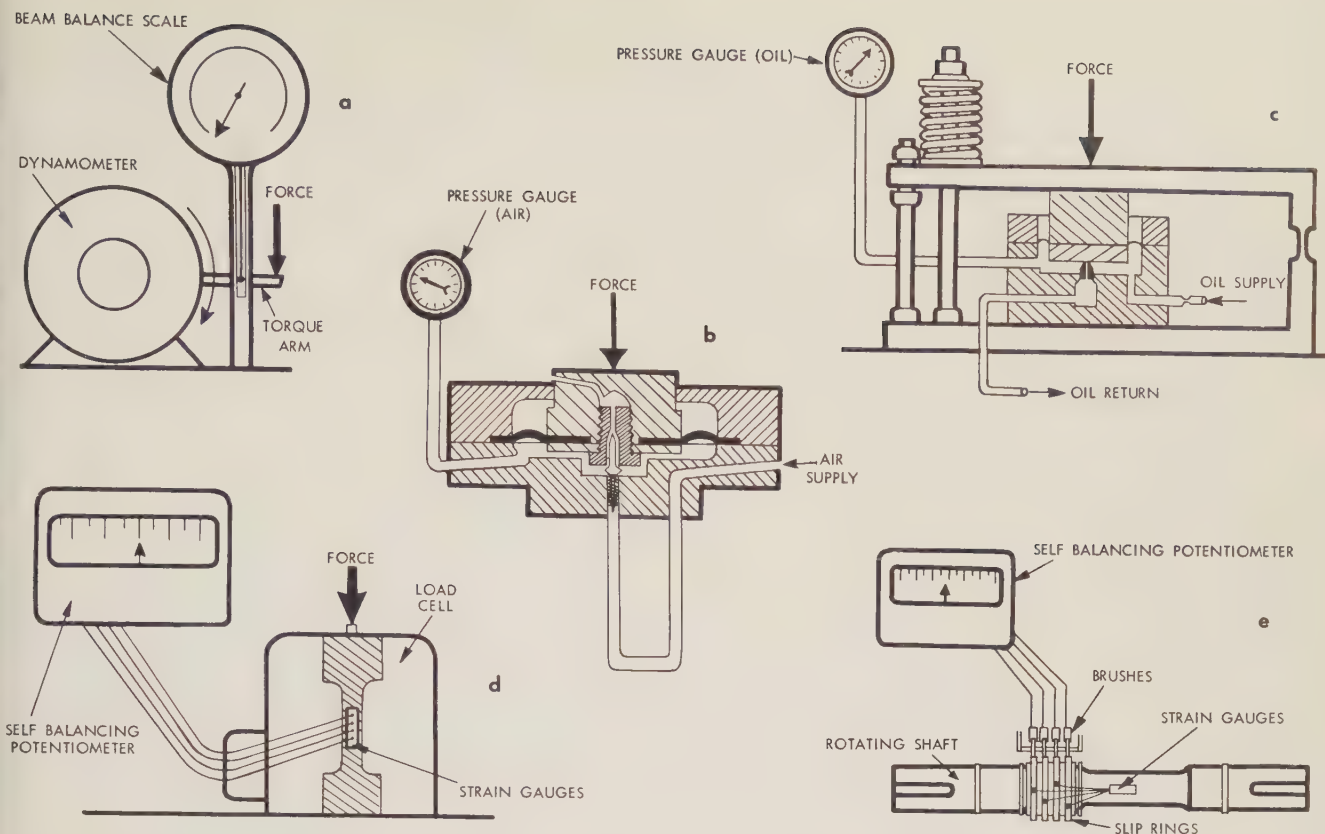
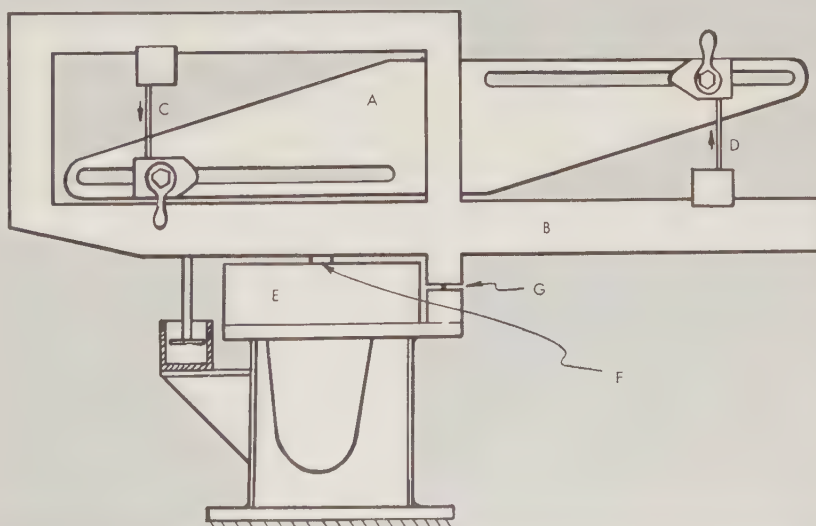


Fig. 5—Torque measuring systems can be mechanical, pneumatic, hydraulic, or electric in operation. The mechanical type (a) is simply the familiar springless scale connected through a load reversing lever system to the dynamometer torque arm. The pneumatic type (b) meters just enough air from a controlled pressure supply into its diaphragm chamber to balance the torque arm force by a pressure times an effective diaphragm area. This pressure is measured by a pressure gage that can be calibrated in force or torque units. The pumped-oil type of hydraulic torque measuring system (c) balances the torque arm force with an oil pressure times an effective diaphragm area. The oil return is metered to produce the required diaphragm chamber oil pressure. A pressure gage measuring this pressure can be calibrated directly in force or torque units. Another hydraulic type of torque measuring system (not shown) consists of a closed cylinder with the torque arm force acting on a

piston. Since the system is sealed, an increase in force on the piston increases the oil pressure in the cylinder which is measured with a pressure gage calibrated in force or torque units. Two types of electric strain gage weighing systems can be used to measure dynamometer torque—the load cell and the torque meter. When the strain gage load cell (d) is used the load from the torque arm is exerted on a load cell consisting of strain gages bonded to a load column. The voltage output, either a-c or d-c depending on excitation, is fed to an indicating and/or recording instrument, such as a self-balancing potentiometer or an oscillograph. The shaft mounted strain gage torque meter (e) measures torque directly by using strain gages bonded to a shaft which is mounted between the engine crankshaft and the driver or absorber shaft. The electrical connections from the strain gages are brought out through slip rings to the indicating and/or recording instrument.

Fig. 6—A load reversing mechanism, such as the Unibeam shown here, serves two purposes: (a) it enables motoring and absorbing dynamometer loads to be measured with a single direction weighing transducer and (b) it permits unloading of the weighing system by means of an air operated cylinder (Fig. 7) to re-zero the indicating dial. The Unibeam shown here is on a pneumatic load cell; however, it also has been adapted by the GM Research Staff for use with the electric and the two hydraulic cells of Fig. 5. Parallelogram *A* is attached to the dynamometer torque arm. Absorbing loads are transmitted to the load arm *B* by cable *C*. Motoring loads are transmitted by cable *D*. Both absorbing and motoring loads exert a downward force on load cell *E* at *F* about the fulcrum *G*.



using the springless beam scale has a linkage system permitting unloading. Any of the remote reading types of torque weighing systems (Fig. 5) can be connected to the dynamometer through a load reversing mechanism (Fig. 6). Such a mechanism allows loads in either direction to be measured as well as making unloading possible. The actual unloading may be accomplished by the force of an air operated cylinder exerted on the dynamometer cradled stator (Fig. 7).

### Dynamometer Control Systems Facilitate Ease of Testing

A dynamometer represents an appreciable investment. A dynamometer, however, is only as useful as its control system is flexible. It is for this reason, therefore, that careful consideration must be given to the method of dynamometer control, both manual and automatic, so that tests may be run with the maximum of ease and in the minimum of time.

The GM Research Staff uses, among others, a typical Ward-Leonard d-c dynamometer control system (Fig. 8) with amplifying generator control on the generator and dynamometer fields to control speed or torque. Extreme flexibility is provided by the system for motoring or absorbing with the dynamometer.

Torque control of a dynamometer can be modified by auxiliary controls to

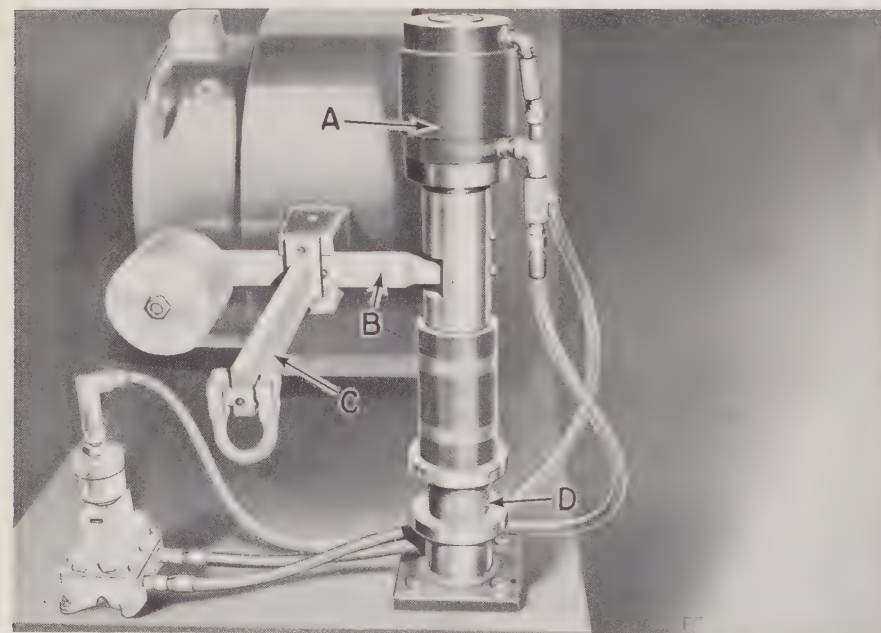


Fig. 7—Dynamometer torque weighing systems can be unloaded by an air operated cylinder *A* exerting a clamping force from both directions on a member *B* attached to the dynamometer torque arm *C*. The system shown is a GM Research Staff modification to the one supplied with the dynamometer. The modification made the locking position more reproducible and adjustment, by means of turnbuckle *D*, easier.

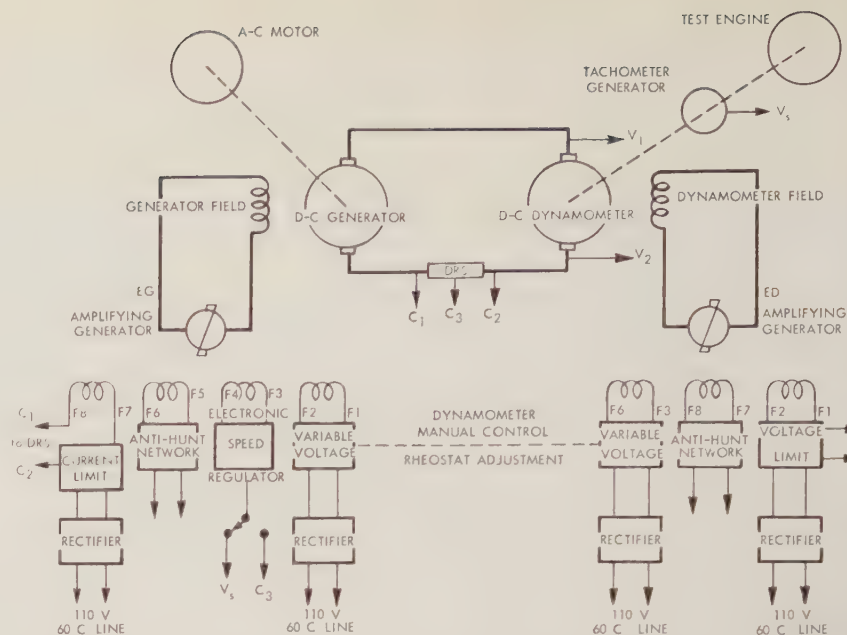


Fig. 8—This diagram indicates a typical Ward-Leonard control system used on d-c dynamometers. Amplifying generator control is used on the generator and dynamometer fields. The armature of the dynamometer is connected electrically to the armature of a "loop circuit." The fields of each are excited separately. The generator is connected mechanically to an a-c inductor motor which, in turn, is connected electrically to building power.

The speed or torque delivered to or absorbed by the dynamometer is controlled by dynamometer armature current or dynamometer field current. Armature current is regulated by controlling the generator field voltage. Dynamometer field current is regulated by controlling the dynamometer field voltage. Both generator and dynamometer field voltages are controlled by amplifying generator systems *EG* and *ED* so that control circuits have low power levels.

Increasing dynamometer armature voltage  $V_1$ - $V_2$  or decreasing dynamometer field voltage increases speed. Normally, speed is increased from zero to base speed by increasing the dynamometer armature voltage with full dynamometer field current. (Base speed is the lowest speed at which a dynamometer can operate at its maximum horsepower). Higher speeds are obtained by decreasing dynamometer field voltage.

For *manual control*, the generator field voltage and dynamometer field voltage are set by a rheostat adjustment to values producing the desired speed at the given load conditions. When the load changes, the speed changes to some extent or vice versa because no feedback control signal is used.

*Speed control* at a particular value is accomplished by comparing a feedback voltage  $V_s$ , from a tachometer generator belted to the dynamometer shaft, with a reference voltage by means of a control regulating amplifying generator field  $F_3$ - $F_4$ . This control circuit changes the generator field proportional to the voltage difference between tach generator and reference voltages. With no voltage difference, the dynamometer runs at the speed selected by the reference voltage setting. Speed regulation possible is within  $\frac{1}{2}$  per cent of operating speed between base speed and top speed,  $\frac{1}{2}$  per cent of base speed from about 20 per cent of base speed to base speed for a change of 100 per cent of rated torque. With small torque changes, speed regulation can be held much closer than this, down to plus or minus 5 rpm or better.

Since dynamometer armature current is proportional to torque at a constant dynamometer field, *torque control* is obtained by substituting a voltage proportional to armature current across the *DRS* resistor in the loop circuit for the tach generator voltage used on speed control. The same electronic control circuit is used as for speed control. Torque control within plus or minus 5 per cent of maximum rated dynamometer torque for a speed change of  $\frac{1}{2}$  top speed of the dynamometer can be expected. On most installations speed control can be held to closer limits than torque control because the feedback system is designed primarily for speed control with torque control as an inexpensive, seldom used addition. The speed feedback signal has a maximum of about 250 v d-c, compared to about 10 v for the torque feedback signal. Amplification with possible anti-hunt circuit modifications might improve torque control.

simulate various road conditions. Conditions of a car climbing a hill can be simulated by a speed boost or grade control which increases the torque proportional to the speed. Wind resistance on a car also can be simulated, but additional torque, proportional to the square of the speed, is required. This is achieved by using two tachometer generators belted to the dynamometer shaft. The output of the first tach generator, which is of the permanent magnetic field type, supplies voltage to the field of the second. The voltage output of the second tach generator, which is proportional to

simultaneous conditions of speed and torque. Timers, relays, and/or servo systems are used to cycle the dynamometer speed controls from speed 1 to speed 2 and the engine throttle controls from torque 1 to torque 2. The servo systems (pneumatic or electronic positioning devices) used by the GM Research Staff have been elaborated upon to vary the rate of speed and/or torque change. Still more elaborate stepping devices, such as switches or control potentiometers, can increase the number of conditions of speed and torque to produce a test cycle approaching that of a road run cycle. The

cycling control method, however, is an open loop type of control with no feedback signals of speed and torque to assure duplication of desired test conditions.

### Feedback Signal Programming

In order to close the loop of the control system and reproduce accurately desired speed and torque programming under varying engine and dynamometer conditions, feedback speed and torque signals are necessary. These signals are compared to the program signals. The error signal adjusts automatically both the

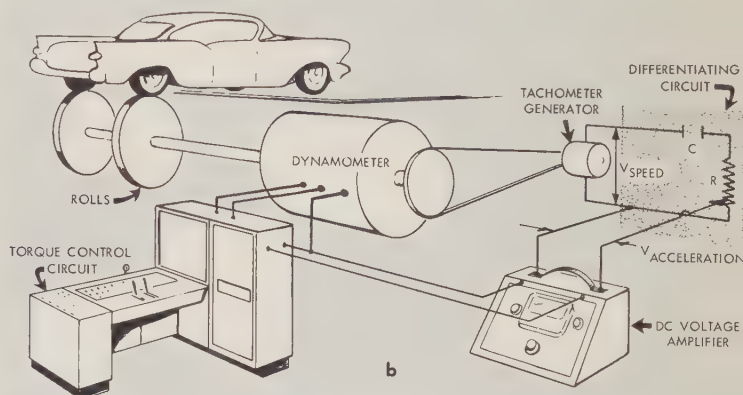
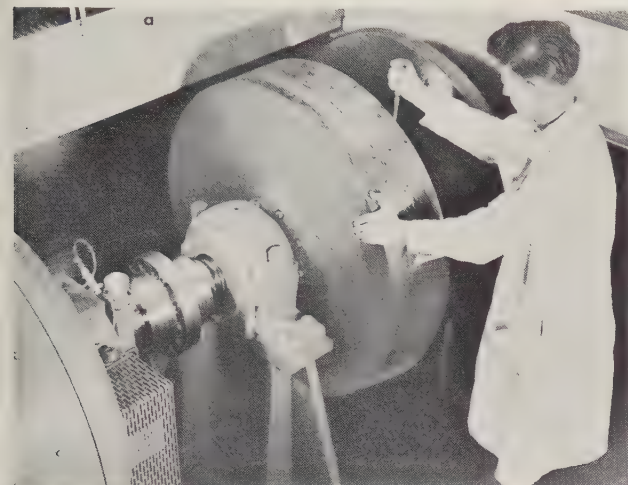


Fig. 9—The inertia of an automobile can be simulated on a chassis dynamometer by using either inertia weights in the form of steel discs or an electronically simulated inertia weight. The inertia weights, shown being mounted on the dynamometer shaft by a Research Staff technician (a), duplicate the effect of a car's weight. The amount of inertia effect desired is controlled by the number of discs used. The electronic method for simulating inertia weight (b), devised by the GM Research Staff, makes use of the electronic control circuit of a dynamometer. A d-c voltage proportional to speed from the tach generator is differentiated to produce a small d-c voltage proportional to car acceleration. This signal, amplified by a commercially available d-c amplifier, is used to modify the torque control circuit to produce a dynamometer torque proportional to car acceleration.

the square of the speed, is then added to the torque control signal. The inertia effect of the mass of a car can be simulated by adding inertia weights (Fig. 9a). The same effect also can be accomplished electrically (Fig. 9b).

### Programming Permits Automatic Control of Dynamometer Test Facility

The usefulness of the dynamometer as an engineering tool has increased greatly with the recent development of programming methods which allow automatic and controlled operation of a dynamometer through a complete test cycle. Two methods of dynamometer programming may be used: (a) cycling control and (b) feedback signal programming.

#### Cycling Control

Cycling control consists primarily of running an engine at two predetermined

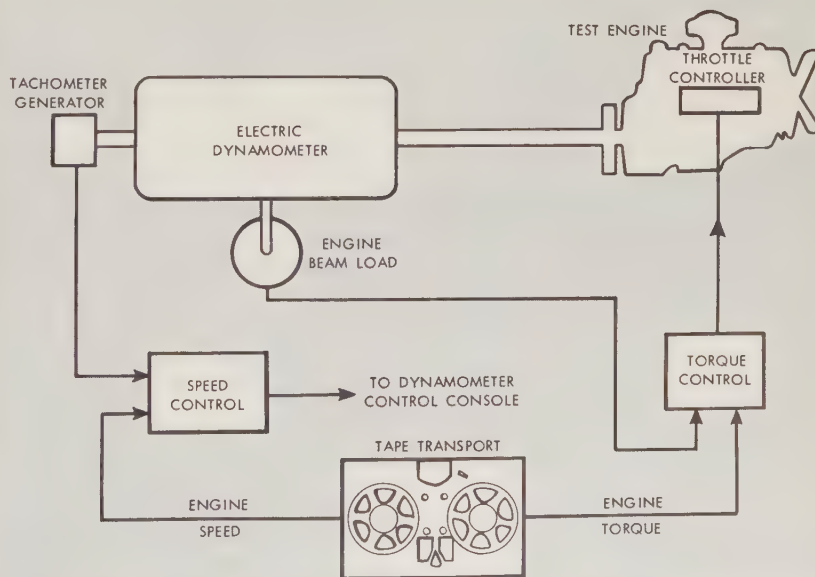


Fig. 10—Programming methods can do much to enhance the usefulness of the dynamometer. This diagrammatic sketch illustrates how a dynamometer subjects an engine to speed and torque conditions which have been recorded previously on an instrumentation-type tape recorder in actual traffic conditions.

dynamometer controls and engine throttle controls to produce the desired program of speed and torque.

Test runs are made on the road with engine speed and torque recorded simultaneously on an instrumentation-type tape recorder using strain gage torque and tachometer generator speed transducers. The tape is then used to furnish the signals, through suitable amplifiers, to program the dynamometer and engine controls (Fig. 10). Feedback signals are furnished by the dynamometer tachometer generator for speed and by the dynamometer torque measuring system for torque. The strain-gage type torque-meter will supply more accurate torque signals during accelerations, since its output includes the inertia torque contributed by the weight of the rotating parts, such as the dynamometer armature.

To make the dynamometer program more complete, other variables, such as the varying temperatures and pressures of the engine oil, water, and transmission, can be tape recorded during a road test. These variables can be controlled, along with speed and torque, with suitable pressure and temperature controllers and feedback transducers on the mediums involved.

#### *Interlocks Protect Personnel and Equipment*

Interlocks refer to a system of sensing transducers, controllers, relays, and contacts used to protect both personnel and equipment from malfunctions and beyond-capacity conditions of operation. The unsafe condition is sensed by the transducer which causes the controller to actuate suitable controls to shut down the equipment and turn on identifying warning lights.

Interlocks supplied by the manufacturer protect dynamometer equipment against occurrences such as armature over-current and over-voltage, field loss, dynamometer and generator over-speed, and dynamometer reversing. Interlocks supplied by the user operate a master relay to stop the dynamometer when de-energized. This arrangement protects the equipment being tested against such things as overheating and loss of pressure, engine ignition, and fuel supply failure. A "fail safe" design, which shuts down equipment when either electrically de-energized or if a transducer fails, is preferred and usually requires a few more relays and/or contacts.

#### *Downtime Reduced by Preventative Maintenance*

An organized program of preventative maintenance saves many hours of expensive downtime. The GM Research Staff has a regular program of inspection checks on specific dynamometer components. Daily calibration checks are made on speed, torque, temperature and other measuring instruments. Monthly inspections include spot checks on speed and torque measuring systems and interlocks. Also, armature bearings are checked with a stethoscope (Fig. 11) along with a check on armature bearing oil flow. Six-month checks include complete speed and torque measuring system inspection and calibration, dynamometer vibration check, a check of oil-floated trunnion bearing lift, inspection of tachometer generator and cradle lock, cleaning and inspecting control potentiometers and contacts, and checking of vacuum tubes. Yearly checks include tightening of all electrical connections, a check of dynamometer interlocks, vibration check on all rotating components, and a check of speed and torque control with and without the engine connected.

#### *Conclusion*

The dynamometer test facility of today is the result of constant developmental work on the part of electrical machine and instrumentation manufacturers. Dynamometer speed and horsepower ratings, accuracies of speed and torque measurement and control, and programming methods have so far kept pace with testing requirements, especially in the automotive industry. But what will be required of the dynamometer in the future? The further development of higher speed engines, the gas turbine for example, will require a still further increase in dynamometer speed and horsepower and still more accuracy in the measurement and control of speed and torque. The use of analog recorded data fed into digital computers for the automatic data reduction of test runs will require still more refinements in instrumentation and data conversion techniques. As in the past, the future requirements of a dynamometer test facility will be met through continued close cooperation between the dynamometer and instrumentation manufacturers and the user of the equipment.



Fig. 11—Armature bearing failures can be detected before serious damage occurs by listening to bearing noise with a stethoscope equipped with a steel rod tip. Shown here is a GM Research Staff technician determining if an excessive dynamometer vibration is caused by defective bearings.

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# The Road Test Trip: An Aid To Automotive Development

By LESTER MILLIKEN\*  
Cadillac Motor Car  
Division

One of the interesting experiences in both the personal and professional lives of some automotive engineers is an assignment known as the road test trip. The road test trip is conducted to broaden the engineer's data about the performance of certain newly-designed components—or a complete car. In most cases, the road test trip seeks the extreme—as well as the normal—conditions of driving under which the component would operate. A group of engineers travel in a convoy of two or more cars equipped with experimental parts, necessary tools, special instruments, and, sometimes, two-way radio for inter-communication. Engineers of the Cadillac Motor Car Division recently conducted two such road test trips—of 2,900 miles and 6,800 miles—which provided information on the performance of new suspension components.

A CONVOY of cars, all of them of one make and of current production, driving at well-spaced intervals, with no unusual markings other than perhaps a tall, extra antenna mounted on the rear bumper—such is the appearance of an activity known as the automotive road test trip.

Engineers of the Cadillac Motor Car Division, as do engineers of other GM automotive Divisions, conduct frequent road test trips to study performance and gather data on experimental designs which are being considered for future use. The trip usually is arranged to include extreme conditions of weather or roads or both.

Most of the automotive developmental work is carried on, of course, in the engineering department, the laboratory, and the facilities of the General Motors Proving Grounds where conditions can be accelerated and controlled. On the Proving Ground at Milford, Michigan, for example, special tests like the 25,000-mile endurance run, performance, braking tests, hill-climbing, or cornering tests can be conducted. At the GM Desert Proving Ground near Mesa, Arizona, tests of air-conditioning systems, tires, or carburetors, are typical activities. GM garage facilities at Manitou Springs, Colorado, are available for use during other testing at Pikes Peak. But the "trip" experience of the road test is valuable in providing engineers with additional impressions and data for their job of designing the best possible quality and performance into the product.

Each Cadillac road test trip is usually organized to gather data on a particular

component or family of components. Suspensions, for example, were studied in two recent trips (Fig. 1 et seq). One trip essentially was for the purpose of studying experimental suspensions under conditions of extreme cold and icing. This was a 2,900-mile winter trip taken through northern Michigan and Canada. Another trip, of 6,800 miles, was taken through western and southern United States primarily to test suspensions under conditions of extreme heat and high humidity.

These are typical trips, representative of a list that could include carburetor trips into northern Minnesota and Canada, brake trips into West Virginia, air-conditioning trips into the humid gulf coast regions, heater trips into the north country, transmission trips to Pikes Peak, and over-all car evaluation trips to the west coast.

Two or more cars are used for the road test trips. They are equipped with the instrumentation required for the particular test, and with a supply of experimental parts and tools for changes en route. When more than two cars make up the convoy, two-way radio communication is provided. These radios, with a power pack in the trunk, special antenna on the rear bumper, and speaker box and microphone on the front seat, permit inter-talk between the cars at distances up to about six miles. The number of engineers making the road test trip varies but in most cases there are at least two engineers in each car. The group usually is made up of engineers with varying amounts of experience ranging from the young engineer with only a few years at

A caravan of cars seeks  
snow-bound roads, desert  
heat or seaside humidity

Cadillac to the more experienced senior project engineers or staff engineers. Quite often the chief engineer joins the group at some point on the trip.

Normal procedure during driving is to change drivers every hour and to change cars every two hours. If the type of road is unusual at any time, the drivers change to different cars to allow a comparison of riding qualities.

When traveling in a group of three or more cars, each car changes position in the convoy at two-hour intervals. This equalizes the gasoline consumption of all of the cars as the tail-end car must drive harder to keep up with the group, particularly when traffic is heavy.

While the road test trip will reach into particular sections of the country for special test purposes, much normal traveling is included which passes by famous land marks and through well-known cities. The trip is a pleasant experience for the engineers while performing their job of gathering important information for further use in the laboratory. The frequent comparisons of car handling and performance, as exchanged over the car radios, the discussions at meals and during the "bull sessions" at night, and the intimate living with the new designs under all conditions is most productive. At the conclusion of the road test trip, the task is completed with the recording and analysis of notes, impressions, and data such as temperatures, pressures, and times. The final result is the engineering report, which can be compared directly with previous tests, since each test is conducted according to an established procedure.

\*For Mr. Milliken's biography and photograph, please see p. 63 of the April-May-June 1957 GENERAL MOTORS ENGINEERING JOURNAL. This is the third paper contributed by Mr. Milliken, staff engineer in the Engineering Department of Cadillac Motor Car Division.



The winter road test trip began in Detroit in March. Engineers of the Cadillac Motor Car Division were headed for northern Michigan and Canada to study the performance of experimental suspension components under conditions of extreme cold and snow. Two 1957 Cadillac cars had been prepared for this trip. They were rebuilt to accommodate the new suspension components and were supplied with the necessary instrumentation and experimental parts plus such winter equipment as tire chains, snow shovels, and tow rope. In Fig. 1, special gauges, attached to the wheel suspension, project through the front fenders to indicate the movement of the suspension.



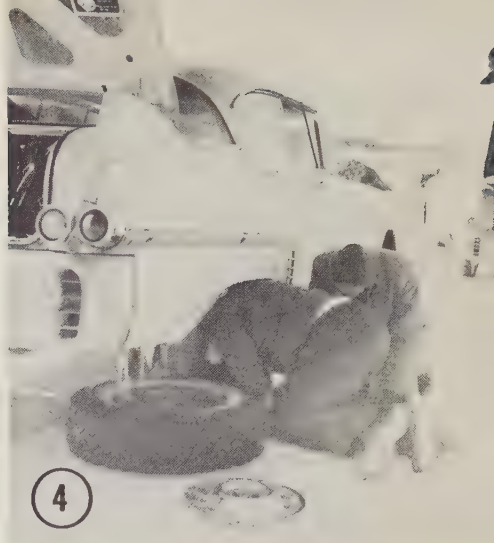
Five engineers started the northern road test trip. The group assembled at a rendezvous point outside of Detroit on March 1 at 7:30 am and proceeded north through Michigan. At the Straits of Mackinac the ferry was on a two-hour departure schedule. The group had ample time for lunch and for an inspection of the new suspension bridge under construction. After crossing the straits, the cars moved along the southern coast of Michigan's upper peninsula (Fig. 2). The winds were high and gusty giving the drivers a good

opportunity to compare handling characteristics of the two cars.

A motel stop was made after 435 miles of driving on the first day. Motels were used wherever possible. They afforded ample and convenient room for the cars, easy grouping of the men, and the informal companionship that is a pleasant part of the test trip. The engineers who made the northern test trip were: (Fig. 3, left to right) Jack Kleberg, Delco Products Division representative, (supplier of suspension components) 2



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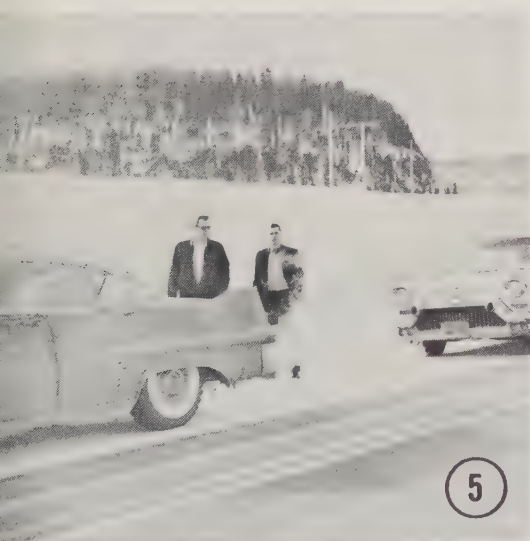
years experience; Dick Nietert, senior project engineer, Suspensions, 15 years experience; John Hoban, assistant staff engineer, Steering and Suspension Group, 10 years experience; Ed Anderson, experimental engineer, Suspensions, 2 years experience; and Les Milliken, staff engineer, Future Development (not shown) 24 years experience. Dick Nietert and Ed Anderson had followed the development of the two suspensions and were familiar with each detail of the designs. They had arranged for the supply of experimental and spare parts as well as necessary tools to be brought for any changes required on the road.

On the second day, starting at 7:00 am with

the temperature at 13° F, the convoy continued north and west through the "Iron" cities of Michigan: Iron Mountain, Iron River, and Ironwood. The snow was four feet deep on the level and piled high along the side of the road. More snow was falling and the wind was blowing it horizontally. Trouble developed with the right rear suspension of one car. The car could be driven further, but the trip was halted—instead of driving to a heated garage—to find out if accumulation of ice or snow had caused the trouble. The rear wheel was removed and the engineers inspected their design (Fig. 4). After repairs and adjustments were made, the group

proceeded through Superior and Duluth stopping at International Falls, Minnesota, at 11:00 pm.

The temperature was 13 below zero on the morning of the third day which, in the words of the engineers, "was just what we wanted." Many of the motels in this northern country had outside electrical receptacles and extension cords for the convenience of motorists who had electrical heaters for cylinder heads. These were not needed by the test cars, however. Local residents said that cars with the newer 12-volt ignition systems had no trouble starting in the coldest weather, even when the cars were left outside. The test group drove north into Canada past the Lake of the Woods and many other beautiful lakes covered with three feet of clean, untrodden snow. The country was desolate and sparsely inhabited but the road was good (Fig. 5).



5



6

Gasoline station facilities often were used for inspection and service work on the test cars (Fig. 6). A hoist was rented and the engineers changed the shock absorbers on the test cars for a comparison on the different roads. The group proceeded to Kenora, Ontario, and followed a secondary road to Redditt, the farthest point north on the trip. The return trip was made to International Falls and to Duluth, where one man left the party and flew back to Detroit. The enormous open-pit iron ore mines of the Mesabi range were frequent scenes along this route. At Port Arthur, Ontario, the next overnight stop, a second member of the party returned to Dayton, Ohio.

For the remainder of the trip, the party was reduced to three men in two cars. The cars continued to Kapuskasing, Ontario, where large paper plants were seen with mountains of pulp wood stored in yards. A road test group from another General Motors Division was encountered here—also searching for cold weather. With the temperature about 2°F, different suspension components were installed and data collected on their performance. Continuing the tests, the group moved on through Canada (Fig. 7) past silver mines and radar warning stations to North Bay and Sault Ste. Marie and finally through Michigan to Detroit.

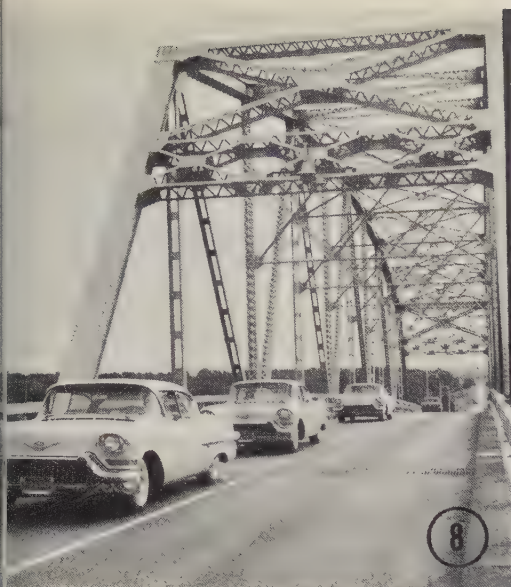


In June, a second road test trip for suspensions was taken to the West, Southwest, and the Gulf Coast sections of the United States. Three cars were used for this trip. Two were test cars, one having air suspension components and the other having a special spring suspension. The third car was a standard 1957 Cadillac in every respect and served as a "bogey" for a standard of comparison. Six men started this test trip. The party

included the Cadillac engineers who made the northern trip (John Hoban, Dick Nietert, Ed Anderson and Les Milliken) plus Bob Meacham, senior project engineer, 6 years experience and Charlton Goodykoontz, senior project engineer, 5 years experience, who were directing the development of the special spring suspension. At later occasions on this test trip, the group was joined by Fred Cowin, staff engineer for suspen-

sions and Fred Arnold, chief engineer. The convoy left Detroit, journeying over familiar roads in Indiana and Illinois, and crossing the Mississippi River at Hannibal, Missouri (Fig. 8).

Each car carried a variety of thermocouples and gauges that registered temperatures and pressures at the desired points for this suspension test trip. The gauges were mounted on a special panel just below the glove compartment and



convenient to the driver and observer. Gauge readings were entered in the log book according to a pre-determined schedule (Fig. 9).

Experimental shock absorbers with different valving combinations were tested during the road trip (Fig. 10). Changes in front shock absorbers were made at convenient roadside spots, while suspension components and the rear shocks were changed on hoists at gasoline stations. The results of each change were entered in the log books.

At Manitou Springs, Colorado, the road test group stayed four days, utilizing the nearby GM Pikes Peak Engineering Test Headquarters and conducting tests at conditions of various altitudes and temperatures. One test car group searched local roads to establish a standard test circuit. A 25-mile route was selected which had all of the necessary types of roads and altitudes required. Shown in Fig. 11 is Rampart Range Road near Manitou Springs. Shock absorber components were tested using various combinations of valving with rubber bushings of different durometers, or hardness, in the suspension.



One test run was made to the top of Pikes Peak to obtain higher altitude and lower temperature (Fig. 12). The road and traffic conditions, however, were not as good as those on the previously selected circuit, where the balance of the road testing was done for better efficiency.

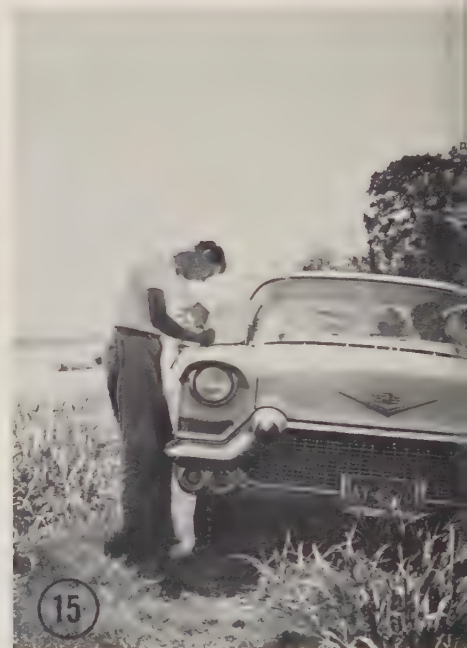




Two of the Cadillac engineers left the party following the Manitou Springs tests and returned to Detroit in one of the test cars. The remainder of the group continued on to Mesa, Arizona, location of the GM Desert Proving Ground. The convoy traveled over the Continental Divide at Monarch Pass, elevation 11,300 ft (Fig. 13). This pass, as well as several others above 10,000 ft elevation, provided ample opportunity to observe the performance of the compressor in the air suspension system.

Frequently, minor changes were made in experimental parts at the motel before starting a new day's run (Fig. 14). Part of the established procedure at the evening stops was to use all cars when going out for meals—again to equalize the driving conditions for all cars. After returning to the motel, the data collected during the day were discussed and plans made for the following morning.

Following two days of tests at the GM Desert Proving Ground, the group was reduced to four men and two cars. The trip continued eastward through El Paso, Del Rio, and Corpus Christi, Texas, to New Orleans. High temperature and



high humidity along much of this route provided thorough testing of the air compressor and air separator of the air suspension car. A 104-mile test circuit was established in the Mississippi delta country below New Orleans. A roadside stop along the Mississippi River is shown in Fig. 15. Many test runs were made on this circuit changing components at the beginning of each run and duplicating speeds and stops as closely as possible.

After two days in Louisiana, the test group drove along the coast to Birmingham, Alabama, and then northward through Tennessee and Kentucky where the hilly country was useful in comparing handling and ride characteristics (Fig. 16). Testing of shocks was continued in this country with roadside locations serving as service pits. Including stopovers at the Pikes Peak Engineering Test Headquarters and at the GM Desert Proving Ground, this road test trip required 20 days and covered about 6,800 miles.



# A Summary of Career Opportunities in General Motors



The chart which appears on the next two pages is a summary, designed to answer questions often asked of GM interviewers by college students and recent graduates. It has the following objectives:

- To acquaint the student or graduate with the kinds of work in GM for which he might be employed
- To show the locations and addresses of GM Divisions and Central Office Staffs
- To help prepare the student or recent graduate for his interview
- To act as a ready source of information during the interview or career discussion for students, interviewers, and guidance people
- To supply information about General Motors to placement officers, deans, and faculty people who discuss careers with students.

It should be kept in mind that the chart is a digest rather than a broad summation designed to answer all questions that may be asked by the student or recent graduate. For example, the Divisions of GM have 126 plants in 70 cities in 19 states throughout the U.S., as well as operations overseas and in Canada which also employ college graduates. Only the Divisional and Central Office headquarters in the U.S. appear on the chart. Most of these units have formalized orientation and train-

ing programs available in both the technical and non-technical areas. Further information may be found in two General Motors publications for those who may be interested. The first is entitled, "The College Graduate and General Motors." Single copies are available to students and may be obtained at the college placement office or by writing General Motors. The second publication, "Job Opportunities in General Motors," describes in some detail GM Staffs, Divisional organizations, and sub-

sidiaries, and outlines career opportunities for graduates of practically every skill and interest. This publication is distributed to colleges only and should be available for use by students in placement offices, libraries, and deans' offices on college campuses.

On the page following the chart are added points of interest for the college student interested in GM. They are concerned chiefly with the question, "How do I go about contacting GM for an interview or facts about employment?"

# A Summary of Career Opportunities in General Motors

The following summary *Kinds of Work* and *Kinds of Graduates Employed* applies to GM Car Divisions, Body and Assembly Divisions, Accessory Divisions, Engine Divisions, Dayton, Household Appliance and GMC Truck Divisions, GM Central Office Technical Staffs, and the GM Canadian Group.

## Kinds of Work for which Graduates Are Generally Employed

- Accounting
- Personnel
- Plant Engineering (planning, developing, and installing and maintaining plant facilities and services)
- Product Engineering (design, development, and testing)
- Production Engineering (processing, methods, time study, machine layout, plant layout, and machine, die, and tool design)
- Purchasing
- Research and Development
- Sales and Service†
- Styling and Design (industrial design, mechanical design, and creative engineering)
- Training for Supervision in Manufacturing† (fabrication, assembly, inspection, production control, packaging, materials handling, and receiving and shipping)

## Kinds of Work for which Graduates are Occasionally Employed

- Legal
- Patent

## Kinds of Graduates Employed

- Business (business administration, marketing, accounting, and finance)
- Engineering (mechanical, electrical, industrial, metallurgical, chemical, aeronautical, civil, and ceramic)
- Law
- Liberal Arts (all majors)
- Science (physicists, chemists, and mathematicians)
- Others (foundry, styling, and design)

Divisions and Staffs of General Motors	Location	Products and Services
Buick Motor Division	1051 E. Hamilton Avenue Flint 2, Michigan	Passenger cars
Cadillac Motor Car Division*	2860 Clark Avenue Detroit 32, Michigan	Passenger cars
Chevrolet Motor Division*	3044 W. Grand Boulevard Detroit 2, Michigan	Passenger cars and trucks
Oldsmobile Division	1014 Townsend Street Lansing 21, Michigan	Passenger cars
Pontiac Motor Division	196 Oakland Avenue Pontiac 11, Michigan	Passenger cars
Buick-Oldsmobile-Pontiac Assembly Division*	3044 W. Grand Boulevard Detroit 2, Michigan	Assembly of passenger cars
Fisher Body Division*	30001 Van Dyke Avenue Warren, Michigan	Body assembly
Ternstedt Division*	6307 W. Fort Street Detroit 9, Michigan	Automotive body hardware
AC Spark Plug Division*	1300 N. Dort Highway Flint 2, Michigan	Major automotive and aircraft parts and accessories and electronic equipment for guided missiles and other applications
Brown-Lipe-Chapin Division*	Town Line Road Syracuse, New York	Automotive accessory parts
Central Foundry Division*	37 Florence Street Saginaw, Michigan	ArmaSteel and grey iron and malleable iron castings
Delco Radio Division*	700 E. Firmin Street Kokomo, Indiana	Automobile radios and semi-conductor devices
Delco-Remy Division*	2401 Columbus Avenue Anderson, Indiana	Automotive electrical equipment and batteries
Detroit Transmission Division	Willow Run Plant Ypsilanti, Michigan	Passenger car and truck Hydra-Matic automatic transmissions

Divisions and Staffs of General Motors	Location
Guide Lamp Division	2915 Pendleton Avenue Anderson, Indiana
Harrison Radiator Division*	Washburn at Walnut Lockport, New York
Hyatt Bearings Division*	427 Middlesex Street Harrison, New Jersey
New Departure Division*	269 N. Main Street Bristol, Connecticut
Rochester Products Division	1000 Lexington Avenue Rochester 3, New York
Saginaw Steering Gear Division	3900 Holland Avenue Saginaw, Michigan
United Motors Service Division*	3044 W. Grand Boulevard Detroit 2, Michigan
Allison Division*	4700 W. 10th Street Indianapolis 6, Indiana
Cleveland Diesel Engine Division	2160 W. 106th Street Cleveland 11, Ohio
Detroit Diesel Engine Division	13400 W. Outer Drive Detroit 28, Michigan
Diesel Equipment Division	2100 Burlingame, S.W. Grand Rapids 1, Michigan
Electro-Motive Division*	9301 55th Street La Grange, Illinois
Euclid Division	1361 Chardon Road Cleveland 17, Ohio
Fabricast Division*	Third and Monon Street Box 271 Bedford, Indiana
Delco Appliance Division	391 Lyell Avenue Rochester 1, New York
Delco Products Division	329 E. First Street Dayton 1, Ohio
Frigidaire Division	300 Taylor Street Dayton 1, Ohio
GMC Truck and Coach Division	660 South Boulevard E Pontiac 11, Michigan
Inland Manufacturing Division	2727 Inland Avenue Dayton 1, Ohio
Moraine Products Division	1420 Wisconsin Boulevard Dayton 1, Ohio
Packard Electric Division	Dana Street, N.E. Warren, Ohio

\*These Divisions have plant locations in other cities in addition to the addresses shown. These locations may be found in the booklet, "The College Graduate and General Motors." These plants also have facilities for interviewing college graduates.

†Opportunities for both technical and non-technical graduates.

# A Summary of Career Opportunities in General Motors

Products and Services
Automotive electrical lighting equipment
Automotive radiators, thermostats, air conditioning systems, transmission oil coolers, heaters, defrosters, industrial and marine heat exchangers, aircraft oil coolers, inter-coolers, and gas turbine regenerators
Roller and tapered bearings and parts for many industrial applications
Ball bearings for every application, coaster brakes, steel balls, and sprag clutches
Carburetors, fuel injection systems, automotive and refrigeration steel tubing, automotive cigarette lighters, locks and keys, and fuel pumps
Power and manual steering gears, propeller shafts, transmission parts, ball bearing screws, and splines for aviation and other uses
Automotive service parts and equipment distribution
Turbo-jet and turbo-prop aircraft engines, heavy-duty transmissions for ordnance and commercial vehicles, Diesel locomotive parts, precision bearings, and Aeroproducts propellers
Large marine Diesel and stationary gas engines and free piston gasifiers
Diesel engines for marine, industrial, petroleum, transportation, and construction equipment
Diesel fuel injectors, hydraulic valve lifters, gas turbine fuel nozzles, and other components
Diesel locomotives, mobile generating plants and large Diesel engines
Earthmoving equipment
Light alloy castings and heat-resistant heavy alloy castings for the automotive, locomotive, aircraft, and other industries
Automotive appliance motors, servo-mechanisms, home heating and air conditioning, fractional hp motors, and electrical and electronic controls
Fractional hp and industrial motors, a-c and d-c generators, electrical and hydraulic controls, automotive shock absorbers, and suspension units
Electric appliances for home and industrial use
Trucks, commercial vehicles, coaches, and buses
Rubber, plastic, metal, and friction material products
Hydraulic brake equipment, bearings, powder metal products, and frictional elements
Automotive and aircraft cable products and fractional hp motors

Divisions and Staffs of General Motors	Location	Products and Services
<b>GM CENTRAL OFFICE TECHNICAL STAFFS</b>		
Engineering Staff (including GM Proving Ground)	GM Technical Center Detroit 2, Michigan	Advanced engineering design, development and testing of automotive products
Process Development Staff	GM Technical Center Detroit 2, Michigan	Manufacturing research and development of new production techniques
Research Staff	GM Technical Center Detroit 2, Michigan	Fundamental and long-range scientific and engineering research for the advancement of technology
Styling Staff	GM Technical Center Detroit 2, Michigan	Appearance design for both automotive and non-automotive products
<b>CANADIAN GROUP</b>		
Frigidaire Products of Canada, Limited*	Scarborough, Ontario Canada	Frigidaire products for Canada
General Motors of Canada, Limited*	William Street E. Oshawa, Ontario Canada	Manufacture and assembly of GM cars, trucks, and automobile engines in Canada
General Motors Diesel, Limited	East Oxford Street London, Ontario Canada	Diesel locomotives, engines, and power generating units
McKinnon Industries, Limited	Ontario Street St. Catharines, Ontario Canada	Parts, assemblies, V-8 engines, and accessories for Canadian-built passenger cars and trucks and other automotive parts and products

• • • • • The following summary *Kinds of Work* and *Kinds of Graduates Employed* applies to the Finance Group. • • • • •

Kinds of Work for which Graduates Are Employed		Kinds of Graduates Employed	
<ul style="list-style-type: none"><li>● Accounting</li><li>● Financial</li><li>● Legal</li><li>● Personnel</li></ul>	<ul style="list-style-type: none"><li>● Public Relations</li><li>● Purchasing</li><li>● Insurance</li><li>● Sales and Service†</li></ul>	<ul style="list-style-type: none"><li>● Business Administration</li><li>● Finance</li><li>● Liberal Arts (all majors)</li></ul>	<ul style="list-style-type: none"><li>● Marketing</li><li>● Mathematics</li><li>● Law</li></ul>

Divisions and Staffs of General Motors	Location	Products and Services
General Motors Acceptance Corporation	1775 Broadway New York 19, New York	Wholesale and retail financing for dealers in GM Products
Motors Holding Division of General Motors	3044 W. Grand Boulevard Detroit 2, Michigan	Capital and financing for retail dealers in GM automobiles
Yellow Manufacturing Acceptance Corporation	3044 W. Grand Boulevard Detroit 2, Michigan	Wholesale and retail financing for GMC trucks, Euclid earthmoving equipment, Detroit Diesel engines, and allied heavy-duty equipment

• • • • • The following summary *Kinds of Work* and *Kinds of Graduates Employed* applies to the Insurance Group. • • • • •

Kinds of Work for which Graduates Are Employed		Kinds of Graduates Employed
<ul style="list-style-type: none"><li>• Adjusting</li><li>• Office Management</li><li>• Sales</li><li>• Underwriting</li></ul>		<ul style="list-style-type: none"><li>• Business Administration</li><li>• Liberal Arts</li></ul>

Divisions and Staffs of General Motors	Location	Products and Services
General Exchange Insurance Corporation	1775 Broadway New York 19, New York	Fire, theft, and collision insurance for automobiles
Motors Insurance Corporation	1775 Broadway New York 19, New York	Fire, theft, and collision insurance for automobiles

Offices of the Finance and Insurance Groups are located throughout the U. S. Contacts for employment information may be made to these zone and branch offices or to the addresses indicated. Consult the telephone directory for addresses of local offices.

# Information About Other GM Units

There are a number of other units within General Motors which are not listed on the preceding chart because they either differ considerably in their responsibilities and functions from those listed or warrant special comment in regard to the employment possibilities and information they have to offer the college graduate. The chart below clarifies the employment picture in regard to these. All of these units, with the exception of General Motors Institute, do not generally employ college people immediately upon graduation. Rather, they normally hire college graduates, who have gained considerable experience related to the more specialized functions of these Staffs, either by way of promotion from within GM or from outside.

GENERAL MOTORS CENTRAL OFFICE STAFFS	Divisions and Staffs of General Motors	Location	Responsibilities and Functions	Kinds of Work for which Graduates Are Employed	Kinds of Graduates Employed
	General Motors Institute	Chevrolet at Third Flint 2, Michigan	Central training and educational agency of General Motors	• Teaching	• Business Administration • Engineering • Social Studies • Science • Mathematics
	Financial Staff	3044 W. Grand Boulevard Detroit 2, Michigan and 1775 Broadway New York 19, New York	Financial analysis in the determination of operating policies of management	• Accounting • Finance • Insurance	• Accounting • Business Administration • Finance • Mathematics
	Business Research Staff	3044 W. Grand Boulevard Detroit 2, Michigan	Long-range studies of economics and business trends for the guidance of management		
	Distribution Staff	3044 W. Grand Boulevard Detroit 2, Michigan	Co-ordination of overall product sales and service activities, policies, and problems		
	Manufacturing Staff	3044 W. Grand Boulevard Detroit 2, Michigan	Co-ordination of scheduling procurement, real estate, transportation, communications, and other manufacturing activities		
	Personnel Staff	3044 W. Grand Boulevard Detroit 2, Michigan	Co-ordination of labor relations and personnel administration activities		
	Public Relations Staff	3044 W. Grand Boulevard Detroit 2, Michigan	Interpretation of GM policies to the public and keeping management informed of public attitudes		
	Legal Staff	3044 W. Grand Boulevard Detroit 2, Michigan and 1775 Broadway New York 19, New York	General control of all matters of legal import concerning GM		College students interviewed directly upon graduation and after having passed the Bar examination. Lawyers with experience, and by virtue of their specialization, also employed from outside GM
	Argonaut Realty Division	485 W. Milwaukee Detroit 2, Michigan	Real estate, rental and leases, building design, and supervision of building construction		Opportunities for architects, structural, mechanical, and electrical engineers, draftsmen, liberal arts, and business graduates, and other categories.
OVERSEAS	General Motors Overseas Operations Division	1775 Broadway New York 19, New York	Manufacturing and distribution of GM products outside the U.S. and Canada		Opportunities for Engineering, Liberal Arts, and Business Administration graduates in Detroit and New York offices but not usually for overseas assignment

## Securing a GM Interview and Employment Information

### Information

College graduates and near graduates interested in a future with General Motors can contact their placement officers for information about GM and its Divisions. If you are interested in more specific information about the Division of your choice, information is available in the publications described on the introductory page to the chart, or at the Divisional and Staff central offices indicated on the chart.

### Interviews

Members of the General Motors Personnel Staff are acquainted with current

Divisional and Staff employment requirements and opportunities. They visit campuses to interview students interested in an industrial career, in order to select those who qualify for employment consideration somewhere in the GM organization.

After the campus interview, qualification summaries of selected students are referred to the GM units having employment openings. Upon review of these summaries, a Division or Staff activity may then invite the student for an interview regarding a specific job assignment or training program. This on-the-spot interview gives members of manage-

ment an opportunity to meet the graduate and, in turn, gives the graduate an opportunity to see the organization and the job before any commitments are made. Final employment of graduates rests entirely with the individual Divisions and Staffs.

If General Motors representatives are not scheduled to visit your campus and you are interested in GM employment opportunities, contact any of the units listed on this chart, or one of the three following offices:

#### Director

Salaried Personnel Placement  
General Motors Corporation  
9-260 General Motors Building  
Detroit 2, Michigan

#### Manager

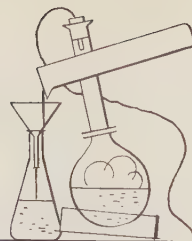
Dayton Salaried Personnel Placement  
General Motors Corporation  
300 North Taylor  
Dayton, Ohio

#### Manager

New York Salaried Personnel Placement  
General Motors Corporation  
1826 General Motors Building  
New York 19, New York

This chart can be obtained either singly or in quantities by writing the above Detroit address.

# The Importance of Complete Disclosures for Chemical Inventions



By JOHN T. MARVIN  
Patent Section  
Dayton Office Staff

THE chemical invention is no different legally than one in the fields of mechanics or electricity. It must meet the same statutory requirements. This means that the chemical invention must either be a new and useful art, machine, process of manufacture, or composition of matter or a new and useful improvement in any of them. If these requirements are met, a patent may be obtained.

The patent for a chemical invention must include a claim or claims which will be both a definition and an assertion of the invention. This is a statutory requirement prescribed for the very purpose of defining precisely what the invention is. The definition must be justified fully by the disclosure, that is, the description of the invention.

The scope of the claim or claims of an application is limited by its specification or description. In mechanical and electrical applications and patents, the U.S. Patent Office and the courts are rather liberal in reading into the specification equivalent structures so that the disclosure of a single embodiment will often be adjudged as full support for broad claims. With a chemical invention, this is not the case. Here is where the chemical invention and related patent applications differ from those in the other arts.

One of the grounds for refusal of claims most used by the U.S. Patent Office in chemical applications is that of *insufficient disclosure*. This means that the disclosure is either insufficient to support *broad* claims due to lack of equivalents and ranges of proportions of ingredients or is insufficient to support *any* claim.

## *Incomplete Disclosures Give Limited and Insufficient Protection*

When the disclosure of a chemical invention is not complete enough to support broad claims, the patent claims which are obtained ultimately may be unduly limited so that the invention is insufficiently protected. Persons skilled in the art may avoid such patent claims by using equivalent chemical materials not specifically set forth or claimed in the

disclosure. This is because the courts, in chemical cases, have not applied broadly the doctrine of equivalents. The courts hold that chemistry is an experimental science and pre-vision is impossible.

For example, consider the case of a disclosure which sets forth only one acid and one salt as materials to be reacted and also sets forth the manner in which the reaction takes place. In this case, the Patent Office will require the claims to be limited to the specific reaction between the one acid and the one salt disclosed. It will not permit the use of the broad term "acid" in combination with the salt. As a result, no broad coverage can be obtained. This differs from a case for a mechanical invention where an inventor, for example, may disclose only a leaf spring as a means for providing a yieldable force. This generally permits the inventor to broadly claim any resilient or yieldable means for providing a yieldable force, such as elastomeric members or coil springs. Thus, the mechanical patent claim can usually be based upon a disclosure of a single workable embodiment of the device and may be claimed broadly, since mechanical equivalents are held to be well known to those skilled in the art.

## *Insufficient Disclosures Also Cause Delay and Extra Expense*

If the disclosure of a chemical application is insufficient to support any claim it is then necessary to refile the application with added subject matter. This causes a loss of the early filing date on the added material and creates unnecessary work and expense. A rejection of a chemical application of this character is usually brought about by the absence of ranges of ingredients which will produce a workable compound or insufficient detail to define properly a claimed material.

## *Inventor Should Present Precise Disclosure*

The technical restrictions that are imposed on chemical disclosures require added responsibility on the part of the

## **Complete protection requires a complete disclosure**

inventor and the patent attorney who endeavor to protect adequately the invention. In this respect, the chemical inventor can be a tremendous help to the patent attorney, and simultaneously obtain better patent protection, if he uses an objective approach to the over-all problem. Disclosures sent to the patent attorney should be precise. They should include a number of examples showing proportions of ingredients and precise methods for mixing the ingredients together with time and temperature limitations where these factors are important. The disclosure should set forth alternative or equivalent materials whenever possible, and it should include technical names for all trade name items.

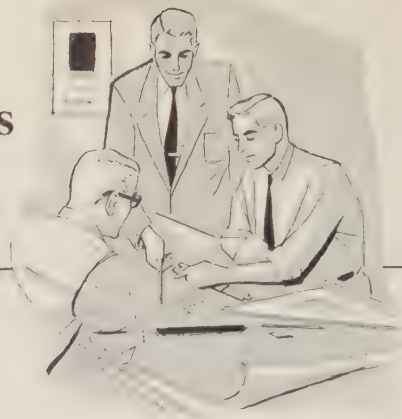
In general, a chemical disclosure should give the patent attorney all the information known about the invention regardless of whether the information seems relevant or not. The attorney can then sift the material and discard what is not needed, although this added information often helps toward a more intelligent understanding of the problem.

This may appear to be a great deal of unnecessary work on the part of the inventor. It should be pointed out, however, that every inventor wishes to have his invention protected to the fullest extent. In the chemical arts, the only possible way to obtain breadth of protection is by a full, complete, and detailed disclosure. In this way, the disclosure will support broad claims. If the alternative materials are not available and cannot be found, and if ranges are not available and cannot be determined, all that can be hoped for is a narrow patent specifically limited to the single embodiment set forth.

In summary, complete chemical patent disclosures help the patent attorney prepare an application which will ultimately produce a valid patent providing adequate protection.

# Notes About Inventions and Inventors

Contributed by  
Patent Section  
Dayton Office Staff



The following is a general listing of patents granted in the names of General Motors employees during the period January 1, 1957 to April 30, 1957.

## *AC Spark Plug Division Flint, Michigan*

• **Donald B. Lewis**, (*Northwestern University and B.S.E.E., Marquette University, 1949*) project engineer, Automotive Engineering Department, inventor in patents 2,778,444 and 2,781,861 for an air cleaner assembly and air cleaner, respectively.

• **Joseph N. Heller**, (*B.S.M.E. and B.S.E.E., Clemson Agricultural College, 1928*) assistant staff engineer, Automotive Engineering Department, and **Wesley W. McMullen**, (*B.S.M.E., University of Michigan, 1934*) staff engineer, Automotive Engineering Department, inventors in patent 2,779,431 for a filtering device.

• **Ross W. Buchanan**, (*B.S., Michigan State University, 1932*) supervisor, Chemical Research Department and **John Gold**, (*B.S.Ch.E., University of Michigan, 1939*) senior experimental chemist, Chemical Research Department, inventors in patent 2,779,687 for a fuel pump diaphragm and process for making same.

• **James H. Devoe**, (*General Motors Institute*) field engineer, Automotive Engineering Department, inventor in patent 2,781,914 for sock type filters.

• **James D. Karn**, (*B.S.M.E., Purdue University, 1948*) senior project engineer, Engineering Department, **John D. McMichael**, (*Michigan State University*) product engineer, Automotive Engineering Department and **Wesley W. McMullen\***, inventors in patent 2,783,855 for a cleaner silencer structure.

• **Wesley W. McMullen\***, inventor in patents 2,783,857 and 2,789,662 for a cleaner silencer and an air intake device for engines, respectively.

• **Robert W. Smith**, (*B.S., University of Chattanooga, 1929 and Ph. D., University of Michigan, 1933*) supervisor, Physics and Metallurgy Laboratory, Research Engineering Department and **Karl Schwartzwalder**, (*B.Cer.E., and M.Sc., The Ohio State University, 1937*) chief ceramic engineer, Ceramic Laboratory, inventors in patent 2,786,819 for a resistor.

• **Benjamin Schmittke**, checker, Engineering Drafting Department, inventor in patent 2,789,361 for a lead gage.

• **Bertil H. Clason**, (*Coethen Polytechnikum, Germany, and Tekniska Skolan, Sweden*) senior project engineer, Automotive Engineering Department, inventor in patent 2,790,043 for a pressure responsive device.

## *Allison Division Indianapolis, Indiana*

• **Robert P. Atkinson**, (*B.S.M.E., Purdue University, 1935*) section chief, Advance Design and Development Department, inventor in patent 2,778,565 for a turbine and compressor coupling.

• **Fred W. Hoeltje**, (*B.S.M.E., Bradley University, 1940*) senior project engineer, Advance Design and Development Department, inventor in patent 2,779,435 for a centrifugal breather.

• **Floyd G. Dougherty**, (*B.S.M.E., Purdue University, 1939*) chief, Combustion Section, Engineering Department, inventor in patent 2,781,637 for a combustion chamber with fuel vaporizer.

• **Arthur W. Gaubatz**, (*B.S.M.E., University of Wisconsin, 1920*) senior project engineer, Experimental Engineering Department, inventor in patents 2,784,354 and 2,786,667 for an electrical installation and a control apparatus, respectively.

## *Aeroproducts Operations Allison Division Dayton, Ohio*

• **Robert C. Helke**, (*University of Dayton*) experimental engineer, Actuator Engineering Department, inventor in patent 2,778,462 for a fluid motor and transmission.

• **Russell E. Line**, (*B.S.Aero.E., Indiana Technical College, 1942*) senior project engineer, Engineering Department; **Clifford B. Wright**, (*A.B., Wittenberg College, 1938*) chief engineer, Aircraft Products, **Thomas Barish**, not with General Motors, and **Charles F. Irwin**, not with General Motors, inventors in patent 2,780,298 for a blade seal assembly.

• **Kenneth L. Berninger**, (*Purdue University*) senior project engineer, Engineering Department and **Calvin C. Covert**, (*B.S.M.E., University of Cincinnati, 1950*) senior engineer, Engineering Department, inventors in patent 2,781,053 for a valve assembly.

• **Roy C. Bodem**, (*University of Dayton*) designer, Engineering Department, inventor in patent 2,782,766 for an actuator locking means.

• **Clifford B. Wright\***, inventor in patent 2,782,862 for a propeller.

• **Mack O. Blackburn**, (*The Ohio State University*) chief test engineer, Engineering Department, **Selwyn E. Garber**, (*Sinclair College*) experimental engineer, Engineering Department, and **Clifford B. Wright\***, inventors in patent 2,786,538 for an aircraft propeller blade.

• **Howard M. Geyer**, (*B.S.I.E., University of Alabama, 1940*) chief research engineer, Engineering Department, inventor in patent 2,787,749 for a motor speed control system.

*Buick Motor Division  
Flint, Michigan*

• **Harry C. Doane**, now assistant to the vice president in charge of GM Engineering Staff, inventor in patent 2,781,597 for an ornamental article.

• **Charles D. Holton**, (B.S.M.E., University of Michigan, 1931) engineer, Engineering Department, inventor in patent 2,787,915 for a power transmitting connection.

*Cadillac Motor Car Division  
Detroit, Michigan*

• **Chester J. Glowzinski**, senior project engineer, instruments, lights, and accessories, Engineering Department, and **Phillip W. Maurer**, (General Motors Institute, 1934) staff engineer, Engineering Department, inventors in patent 2,781,425 for switch controllers.

• **John Hassler**, senior welding engineer, Methods and Equipment Department, inventor in patent 2,783,362 for a multiple electrode arc welding assembly.

• **William Martin**, (B.E.E., Yale University, 1947) senior project engineer, heating and air conditioning, Engineering Department, and **Warren D. Lange**, (General Motors Institute, 1951) project engineer, Engineering Laboratory, inventors in patent 2,786,173 for a motor control system.

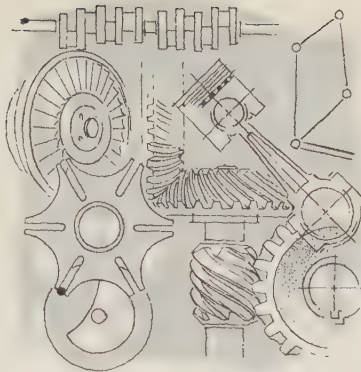
*Chevrolet Motor Division  
Detroit, Michigan*

• **Edward N. Cole**, (General Motors Institute, 1933) vice president of GM and general manager of Chevrolet Motor Division, and **Edward J. Naudzius**, (B. Aero.E., University of Detroit, 1941) design engineer, Passenger Car Chassis Group, Engineering Department, inventors in patent 2,779,498 for a fuel tank and fitting.

*Delco Appliance Division  
Rochester, New York*

• **John B. Dyer**, deceased, and **Cyril T. Wallis**, (Technical School, Cambridge, England) patent and new devices contact, Engineering Department, inventors in patent 2,785,430 for a windshield cleaning apparatus.

• **Bernard D. Andrews**, (B.S.E.E., Clarkson College of Technology, 1948) project



engineer, Engineering Department, inventor in patent 2,785,580 for a gear assembly.

*Delco Products Division  
Dayton, Ohio*

• **Paul J. Long**, (B.S.M.E., University of Cincinnati, 1941) section engineer, Engineering Department, and **Harold E. Schultze**, project engineer, Engineering Department, inventors in patent 2,785,774 for a shock absorber with liquid cooling.

• **Joseph F. Bertsch**, (B.S.M.E., University of Cincinnati, 1948) now research engineer, Research and Development Department, Chevrolet Motor Division, inventor in patent 2,786,454 for a power steering control valve.

• **George W. Jackson**, (B.S.M.E., Purdue University, 1937) engineering manager, Automotive and Mechanical Products, inventor in patent 2,787,475 for a load controlled valve assembly for vehicle air spring.

*Delco Radio Division  
Kokomo, Indiana*

• **William R. Kearney**, (B.S.M.E., Purdue University, 1933) senior project engineer, Mechanical Engineering Section, and **Bertram A. Schwarz**, technical assistant to the general manager, inventors in patent 2,775,895 for an automatic radio tuning means.

\*Inventors' names marked with an asterisk have biographical listings noted previously in this issue's Notes About Inventions and Inventors.

• **Kenneth S. Vogt**, (The Ohio State University), senior project engineer, Engineering Department, inventor in patent 2,786,963 for a salute control for automatic headlight dimmer system.

*Delco-Remy Division  
Anderson, Indiana*

• **Paul L. Schneider**, (B.M.E., The Ohio State University, 1921) section engineer of heavy-duty equipment, Engineering Department, and **William H. Taylor**, group leader of switches, Drafting Department, inventors in patent 2,778,228 for a control device.

• **William E. Brown**, (General Motors Institute) staff engineer, Product Engineering Department, and **Harold V. Elliott**, (General Motors Institute) senior project engineer, Product Engineering Department, inventors in patent 2,779,827 for a control device.

• **Charles A. Nichols**, (B.S.M.E., Carnegie Institute of Technology, 1923) now technical assistant to the vice president in charge of Process Development Staff, **George L. Weiser**, chief process engineer, Process Department, and **Richard M. Goodwin**, (B.S.M.E., Purdue University, 1932) senior machine designer, Process Department, inventors in patent 2,781,678 for a cold working apparatus and method.

• **Donald G. Mahony**, (M.E., Purdue University, 1933) process engineer, Process Department, inventor in patent 2,781,952 for a material handling apparatus.

• **Max G. Bales**, (B.S.E.E., Purdue University, 1933) staff engineer, Military Equipment Department, inventor in patent 2,782,247 for an ignition distributor and coil unit.

• **Ward Cole**, product engineer, Engineering Department, inventor in patent 2,782,491 for a method of making an electrical connection.

• **Carl L. Clevenger**, senior engineer, Engineering Department, inventor in patent 2,782,663 for a cold forming apparatus.

• **William E. Brown\***, inventor in patents 2,783,318 and 2,788,407 for a lamp supporting and operating structure and a compartment light and switch, respectively.

• William E. Brown\* and Harold V. Elliott\*, inventors in patent 2,783,324 for a fluid pressure switch.

• Harold V. Elliott\*, inventor in patent 2,785,255 for electric switches.

• T. E. Hollingsworth, (*Purdue University*) process engineer, Process Department, Robert C. Matter, (*B.S.Met.E., University of Illinois, 1943*) chief metallurgist, Process Engineering Department, and Oscar H. Smith, Jr., (*B.S.Met.E., Purdue University, 1949*) engineer, Process Engineering Department, inventors in patent 2,786,003 for nitriding of chromium steel.

• David C. Redick, (*General Motors Institute*) section head, switches and horns, Product Engineering Department, and Verle E. McCarty, (*Purdue University*) engineer, Engineering Department, inventors in patent 2,790,020 for an ignition apparatus.

• Verle E. McCarty\*, inventor in patents 2,788,386 and 2,788,401 for a terminal and an ignition timer, respectively.

• Thomas C. Heath, (*E.E., M.E., Tri-State College*) regulator and relay engineer, Engineering Department, inventor in patent 2,788,412 for a temperature corrected electrical control device.

• Harold J. Cromwell, (*B.S.M.E., Purdue University, 1933*) senior research engineer, Research Department, and Brooks H. Short, (*B.S.E.E., 1931 and M.S.E.E., 1934, Purdue University*) supervisor, engineering research, Engineering Department, inventors in patent 2,788,414 for an electric switch.

#### *Detroit Transmission Division Ypsilanti, Michigan*

• Roy A. Jumisco, (*University of Detroit*) gear engineer, Master Mechanics Department, inventor in patents 2,778,119 and 2,787,896 for an involute curve checking device and a torsional vibration damper, respectively.

• Walter B. Herndon, (*B.S.E., State College of Washington, 1928, and M.S.E., University of Michigan, 1930*) director of engineering and sales, inventor in patents 2,781,682 and 2,790,327 for a torque wrench driven by a fluid coupling and a transmission control system, respectively.

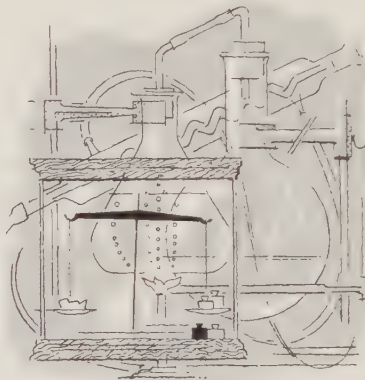
• Robert W. Stapleton, (*B.S., Michigan College of Mining and Technology*) assistant chief engineer, Engineering Department, inventor in patent 2,785,636 for a fluid coupling.

#### *Diesel Equipment Division Grand Rapids, Michigan*

• Herbert H. Black, (*General Motors Institute, 1933*) assistant chief engineer, Product Engineering Department, inventor in patent 2,789,550 for an anti-surge spring means.

#### *Electro-Motive Division LaGrange, Illinois*

• William F. Holin, (*M.E., Konstanz, Germany*) senior project engineer, Engineering Department, inventor in patent 2,781,872 for a slack adjusting connection.



• Corless B. Nelson, (*B.S.C.E., University of Illinois, 1933*) senior designer, Engineering Department, inventor in patent 2,782,054 for a lift truck with hitch-means for maneuvering semi-trailers.

• Robert A. Tinich, (*Illinois Institute of Technology*) designer, Engineering Department, inventor in patent 2,782,294 for illuminated dial instruments.

• Albert N. Addie, (*B.S.M.E., Illinois Institute of Technology, 1944 and M.S.M.E., Case Institute of Technology, 1947*) chief research engineer, Research Department, inventor in patent 2,782,613 for a refrigerating apparatus having a free piston compressor.

• Elmer E. Thiesen, (*B.S.E.E., Iowa State College, 1940*) a-c electrical design

engineer, Engineering Department, inventor in patent 2,783,171 for an insulating method and apparatus.

• Lauren L. Johnson, (*B.S.E.E., University of Nebraska, 1938*) electrical control development engineer, Engineering Department, inventor in patents 2,783,425 and 2,786,170 for a Ward-Leonard speed control system and an electrical control system, respectively.

• Kendall O. Bower, (*B.S.E.E., Iowa State College, 1938*) a-c control engineer, Engineering Department, inventor in patent 2,783,430 for an automatic timed battery charger.

• Rudolph C. Weide, (*M.E. degree, Berlin Technical Institute, Berlin, Germany, 1923*) senior project engineer, Engineering Department, inventor in patent 2,784,265 for a controller.

#### *GM Engineering Staff Detroit, Michigan*

• Daniel C. Wilkerson, (*Maryland State College and U.S. Naval Academy*) engineer, Transmission Development Section, inventor in patent 2,775,910 for a drive control valving and system.

• Carl A. Stickel, (*B.M.E., The Ohio State University, 1928; L.L.B., University of Dayton, 1932; and a Master of Patent Law, University of Dayton, 1934*) patent attorney, Patent Section, Dayton office, inventor in patents 2,780,008 and 2,780,009. The patent in each case is for a domestic appliance.

• Charles A. Chayne, (*B.S.M.E., Massachusetts Institute of Technology, 1919, and Harvard University*) vice president in charge of Engineering Staff, inventor in patent 2,781,750 for an engine construction.

• Oliver K. Kelley, (*B.S., Chicago Technical College, 1925, and Massachusetts Institute of Technology*) now chief engineer, Buick Motor Division and Robert M. Schaefer (*M.E., University of Munich, 1926*) manager, Transmission Engineering Department, Allison Division, inventors in patent 2,782,658 for a composite fluid and gear drive.

• Oliver K. Kelley\*, inventor in patent 2,782,659 for a hydrodynamic torque convertor and gearing.

- **Oliver K. Kelley\*** and **Jack W. Qualman** (*General Motors Institute, 1937*) now assistant chief engineer, Engineering Department, Detroit Transmission Division, inventors in patent 2,781,858 for a vehicle driving and steering transmission and hydraulic control therefor.

- **Maurice A. Thorne**, (*B.A., George Washington University, University of Maryland*) engineer-in-charge, Vehicle Development Section, inventor in patent 2,786,725 for endless track structures for vehicles.

- **Roland V. Hutchinson**, (*Municipal Technical School, Manchester, England*) now on special assignment work for the Engineering Staff, inventor in patent 2,789,438 for an idler mechanism.

- **John Dolza**, retired, **Harry Bielicki**, (*Wayne State University and International Correspondence School*) senior design engineer, Power Development Department, and **Earl Pierce**, no longer with General Motors, inventors in patent 2,789,545 for a windshield wiper motor.

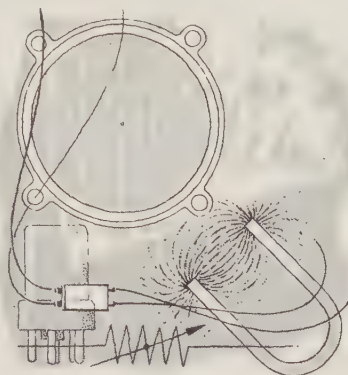
- **John Burnell**, (*Massachusetts Institute of Technology and General Motors Institute, 1941*) now assistant chief engineer, Product Engineering and Development Department, Rochester Products Division and **John Dolza\***, inventors in patent 2,783,510 for a cylinder block coring for V-8 engines.

- **Max Ruegg**, (*M.E., Swiss Polytechnic, 1921*) assistant engineer-in-charge, Structure and Suspension Development Group, and **Von D. Polhemus**, (*B.S.M.E., University of Cincinnati, 1933*) engineer-in-charge, Structure and Suspension Development Group, inventors in patent 2,789,812 for torsion spring devices.

#### *Euclid Division Cleveland, Ohio*

- **Arthur P. Armington**, (*B.S.M.E., Case Institute of Technology*) supervisor, Sales Development Office, and **George E. Armington**, (*B.M.E., 1925, and M.S., 1926, The Ohio State University*) director of engineering, Engineering Department, inventors in patent 2,738,849 for an independently controlled hydraulic power steering means for the front and rear wheels of a vehicle.

- **Raymond Q. Armington**, (*B.I.E., The Ohio State University, 1928*) general manager, **John P. Carroll**, (*Bradley University*) chief product engineer, Engineering Department, **Janis Mazzarins**, (*Technical University, Aachen, West Germany*) senior project engineer, Engineering De-



partment, and **Russell C. Williams**, (*B.S.M.E., University of Illinois, 1932*) manager, research and test, Engineering Department, inventors in patent 2,786,724 for a track suspension.

- **William J. Adams**, retired, and **Edward R. Fryer**, (*General Motors Institute and B.S.M.E., Massachusetts Institute of Technology, 1945*) senior project engineer, Engineering Department, inventors in patent 2,788,999 for a pusher bumper for lever type scraper.

#### *Fisher Body Division Detroit, Michigan*

- **Joseph E. Kubacka**, (*Columbia University, Detroit Institute of Technology, and Wayne State University*) senior engineer-in-charge, Experimental and Development Department, inventor in patent 2,775,997 for a torsion spring seat spring stiffener.

- **Wilfred J. Larabell**, engineer-in-charge, Trim Engineering Department, inventor in patent 2,779,048 for a fastener for floor coverings.

- **Claud S. Semar**, (*Detroit City College, University of Michigan, and Wayne State University*) senior project engineer, Engineering and Drafting Department, inventor in patent 2,779,050 for a door check and hold-open.

- **Larabee T. Kendall**, (*B.M.E., General Motors Institute, 1947*) senior project engineer, Experimental and Development Department, inventor in patent 2,785,738 for a seat spring attachment.

- **Phillip C. Wolliver**, (*Wayne State University*) senior process engineer, Process Development, inventor in patent 2,787,923 for a portable tool for applying spring nut fasteners.

#### *Frigidaire Division Dayton, Ohio*

- **Richard S. Gaugler**, (*B.S.Ch.E., Purdue University, 1922*) supervisor of major product line, inventor in patent 2,778,200 for an ice making apparatus.

- **Richard S. Gaugler\*** and **Edmund F. Schweller**, assistant chief engineer, inventors in patent 2,779,066 for an insulated refrigerator wall.

- **James W. Jacobs**, (*B.S.M.E., University of Dayton, 1954*) section engineer, Appliance Engineering Department, inventor in patents 2,779,163 and 2,780,077 for a vehicle refrigerating apparatus and in patent 2,781,642 for automobile cooling.

- **Joseph R. Pichler**, (*B.I.E., The Ohio State University, 1934*) section head, Commercial Engineering Department, **Richard M. Brubaker**, (*B.M.E., The Ohio State University, 1948*) project engineer, Commercial Engineering Department, **Tom C. Shuler, Jr.**, (*B.S.M.E., Duke University, 1947*) senior project engineer, Commercial Engineering Department, and **Emerson L. Wark**, layout draftsman, Household Engineering Department, inventors in patent 2,779,165 for an ice and water dispenser.

- **James W. Jacobs\*** and **Richard E. Gould**, (*B.S.M.E., 1923, and M.S.M.E., 1927, University of Illinois*) assistant chief engineer, Research and Future Products Engineering Department, inventors in patent 2,779,168 for a refrigerating apparatus.

- **Verlos G. Sharpe**, (*B.S.M.E., Purdue University, 1948*) section engineer, Household Engineering Department, and **Edward C. Simmons**, (*University of Dayton*) senior engineer, Household Engineering Department, inventors in patent 2,779,169 for a refrigerator with can dispenser.

- **Clifford H. Wurtz**, (*B.S., University of Illinois, 1929*) supervisor of major product line, inventor in patents 2,779,173, 2,787,131, and 2,787,136 for a dehumidifier having a unitary evaporator-con-

denser plate, a motor cooling refrigerator, and an oil separator in refrigerating apparatus, respectively.

- **Verlos G. Sharpe\***, inventor in patent 2,780,926 for a wall mounted refrigerating apparatus.

- **Edward C. Simmons\***, inventor in patent 2,781,645 for a heat exchanger.

- **George B. Long**, (*B.S.E.E., Purdue University, 1937*) supervisor, major product line, Research and Future Products Engineering, inventor in patent 2,782,292 for a domestic appliance.

- **George C. Pearce**, (*B.S.M.E., Stanford University, 1924*) section head, Appliance Engineering Department, inventor in patent 2,782,403 for a slotted switch position indicator.

- **Robert Galin**, (*B.S.M.E., Robert College, Istanbul, Turkey, 1947, and M.S.M.E., University of Michigan, 1949*) senior project engineer, Research and Future Products Engineering Department, inventor in patent 2,782,609 for an ice block making apparatus.

- **James A. Canter**, (*B.M.E., The Ohio State University, 1936*) senior project engineer, Commercial Engineering Department, inventor in patents 2,783,083 and 2,784,564 for a combination valve, water pressure regulator, and bubbler and a display case for frozen food, respectively.

- **Edmund F. Schweller\*** and **Edgar C. Robbins**, (*Utilities Institute, Chicago, and Tri-State Training Institute, Wheeling, West Virginia*) draftsman, Household Engineering Department, inventors in patent 2,785,538 for an ice tray flexing device in a refrigerator door.

- **Edward C. Simmons\*** and **Edgar C. Robbins\***, inventors in patent 2,785,539 for an ice ejector tray.

- **Harry F. Clark**, (*E.E., University of Cincinnati, 1921*) senior project engineer, Engineering Department, inventor in patents 2,786,171 and 2,788,413 for a starting and overload control for split-phase electric motor and an electrical apparatus, respectively.

- **Clifford H. Wurtz\*** and **Keith K. Kesling**, (*University of Dayton and Dayton*

*Art Institute*) project and design engineer, Research and Future Products Engineering Department, inventors in patent 2,786,338 for a refrigerating apparatus for cooling liquids.

- **Daniel L. Kaufman**, section head, Commercial Engineering Department, inventor in patent 2,787,130 for a refrigeration expansion valve.

- **Millard E. Fry**, (*B.S.M.E., University of Pittsburgh, 1931*) senior project engineer, Appliance Engineering Department, inventor in patents 2,790,056 and 2,790,886 for a domestic appliance.

- **George W. Schauer, Jr.**, draftsman, Household Engineering Department, inventor in patent 2,790,057 for a domestic appliance.

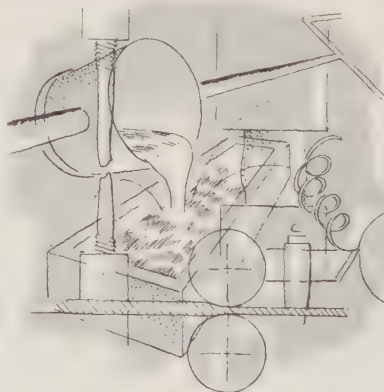
- **Orson V. Saunders**, supervisor, Product Line, Household Engineering Department, and **Carl F. Petkowitz**, (*B.S.M.E., University of Dayton, 1925*) engineer, Engineering Department, inventors in patent 2,790,696 for a refrigerating apparatus.

#### *General Motors Diesel, Limited London, Ontario, Canada*

- **John Houghton**, foreman, Tool Engineering Department, and **Hubert A. Edney**, Tool Engineering Department, inventors in patent 2,784,569 for a rotatable refrigerator with multiple compartments.

#### *GM Overseas Operations Division New York, New York*

- **Hans Mersheimer**, (*Rheinische Ingenieur-schule, Bingen, Germany, 1926*) assistant



chief engineer, Engineering Department, and **Martin Heintke**, (*Technical School, Leipzig, Germany, 1918*) assistant body engineer, Engineering Department, inventors in patent 2,788,223 for base

frames for the substructure of self-supporting vehicle bodies. Both inventors with Adam Opel, A.G., Russelsheim/Main, Germany.

- **Jochem Baumgartner**, (*Technical University, Darmstadt, Germany, 1950*) assistant head, Patent Section, Adam Opel, A.G., Russelsheim/Main, Germany, inventor in patent 2,783,978 for an engine hood construction for automobiles.

- **Mario J. Maina**, (*Regent Street Polytechnic, 1936*) design engineer, Engineering Department, Vauxhall Motors, Ltd., Luton, England, inventor in patent 2,785,776 for a hydraulic brake assembly for road vehicles.

#### *GMC Truck & Coach Division Pontiac, Michigan*

- **Ferdinand R. Eichner**, superintendent, Experimental Sheet Metal Department, inventor in patents 2,779,862 and 2,779,864 for a package rack with vehicle illuminating means and a light rail, respectively.

- **Hans O. Schjolin**, (*B.S., Karlstad College, Sweden, 1920 and B.S., Polytechnical Institute, Mittweida, Germany, 1923*) new development engineer, Engineering Department, inventor in patents 2,782,871 and 2,784,568 for a wheel structure with non-rotating hub cap and a vehicle refrigerating apparatus, respectively.

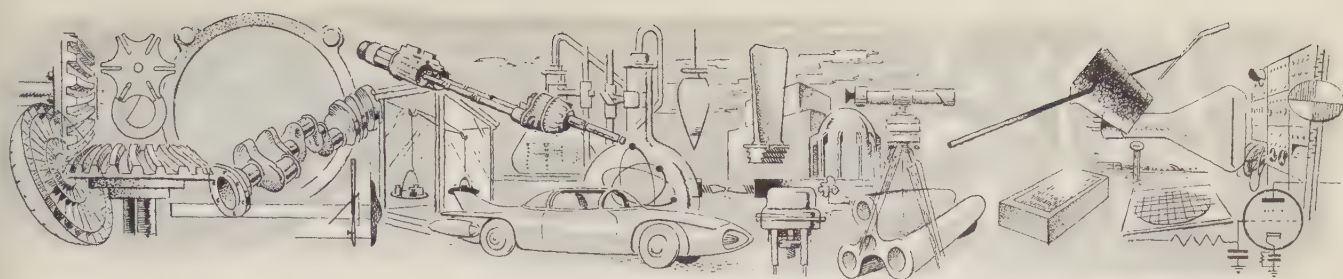
- **Hans O. Schjolin\*** and **Donald K. Isbell**, senior engineer, Engineering Department, inventors in patent 2,788,091 for a wheel brake having multiple force applying webs.

#### *Guide Lamp Division Anderson, Indiana*

- **Robert N. Falge**, (*B.S.E.E., University of Wisconsin, 1916*) technical assistant to the general manager and **Howard C. Mead**, (*Western Reserve University*) chief engineer, inventors in patent 2,783,452 for a combination direction signal lamp.

- **William T. Mears**, experimental engineer, Engineering Department, inventor in patent 2,786,129 for a lamp socket mounting.

- **Myrnest L. Woodward**, electronics engineer, Engineering Laboratory, inventor in patent 2,786,962 for a head-lamp dimmer system.



● **Lyle N. Williams**, (*A.B.Chem., Indiana University*) senior project engineer, Engineering Laboratory, inventor in patent 2,789,464 for a mirror.

*Harrison Radiator Division  
Lockport, New York*

● **Robert F. Caughill**, (*M.E., Clarkson College, 1941*) supervising engineer, industrial section, Engineering Department, inventor in patent 2,782,008 for heat exchangers for fluids.

● **John R. Holmes**, retired, **Robert R. Mandy**, (*B.E.E., Lawrence Institute of Technology, 1945*) supervising engineer, Air Conditioning Section, Engineering Department, and **Lawrence A. Zwicker**, (*Dalhousie University, Halifax, Nova Scotia*) chief engineer, inventors in patent 2,787,888 for air conditioning systems.

*Inland Manufacturing Division  
Dayton, Ohio*

● **Sam B. Miller**, model builder, Experimental Engineering Department, and **Murray S. Millhouse**, (*General Motors Institute, 1941*) project engineer, Engineering Department, inventors in patent 2,776,545 for a power unit for freezing device.

● **Paul E. Clingman**, (*General Motors Institute, 1935*) supervisor, Quality and Control Distribution, inventor in patent 2,782,058 for a connector.

● **G. William Beck**, (*B.I.E., General Motors Institute, 1947*) assistant chief engineer—product design, Engineering Department, and **Howard W. Rentz**, not with General Motors, inventors in patent 2,782,495 for joining of metals.

*Moraine Products Division  
Dayton, Ohio*

● **Paul J. Shipe**, (*B.S. in physical chemistry, Muskingum College, 1934, and M.S. in physical chemistry, The Ohio State University, 1938*) supervisor, engineering laboratory,

Engineering Department, inventor in patent 2,778,742 for a method of impregnating a porous ferrous part with copper.

● **Frederick W. Sampson**, (*M.E. degree, Cornell University, 1924*) section engineer on special assignment, inventor in patents 2,779,166 and 2,786,108 for an ice tray grid and a horn blowing mechanism, respectively.

● **Peter Mushovic**, (*B.S.Met.E., Missouri School of Mines and Metallurgy, 1944*) senior process engineer, Processing Department, and **Harold W. Schultz**, section engineer, Engineering Department, inventors in patent 2,782,498 for a method of making composite stock.

● **Frank W. Brooks**, (*B.S., Case Institute of Technology, 1935*) project engineer, Engineering Department, inventor in patent 2,788,095 for an automatic wear adjustor.

● **Paul J. Shipe\*** and **Athan Stosuy**, no longer with GM, inventors in patent 2,789,901 for a method of making high density sintered parts.

*Oldsmobile Division  
Lansing, Michigan*

● **Stanford Landell**, (*University of Pennsylvania*) now director of engineering sales, Brown-Lipe-Chapin Division, inventor in patent 2,788,100 for a molding retainer.

*Packard Electric Division  
Warren, Ohio*

● **Robert C. Woofter**, (*Fenn College*) chief, Assembly Components Design Section, inventor in patent 2,782,250 for a shielded electrical conductor.

● **Robert E. Kirk**, (*Case Institute of Technology*) product designer, Assembly Components Design Section, inventor in patent 2,782,391 for a waterproof line connector.

*Pontiac Motor Division  
Pontiac, Michigan*

● **Herman S. Kaiser**, body engineer, Engineering Department, inventor in patent 2,779,615 for a latch mechanism.

● **Clayton B. Leach**, (*A.B. in mathematics and chemistry, Park College, 1934 and General Motors Institute*) chassis engineer, Engineering Department, inventor in patent 2,782,775 for an engine interior ventilation system.

● **Stephen P. Malone**, (*B.S.E.E., Swarthmore College and The Ohio State University, 1940*) chassis development engineer, Engineering Department, and **Paul J. Long, Jr.**, no longer with General Motors, inventors in patent 2,790,659 for a shock absorber end mounting.

*GM Research Staff  
Detroit, Michigan*

● **Gerald M. Rassweiler**, (*A.B., Bucknell University, 1924; M.S. in physics, 1926, and Ph.D., 1928, University of Illinois*) assistant head, Physics and Instrumentation Department, and **Edward F. Weller, Jr.**, (*B.S.E.E., University of Cincinnati, 1943*) assistant head, Physics and Instrumentation Department, inventors in patent 2,775,885 for a gas analyzer resonator block.

● **Walter E. Sargeant**, (*B.S.E.E., University of Michigan, 1926*) senior research engineer, Physics and Instrumentation Department, inventor in patent 2,776,379 for a constant frequency power supply.

● **Worth H. Percival**, (*B.S., Iowa State College, 1942, and M.S., Massachusetts Institute of Technology, 1947*) assistant department head, Mechanical Development Department, inventor in patent 2,778,348 for an engine scavenging means.

● **Edward K. Benda**, (*B.S.E.E., Michigan College of Mining and Technology, 1950*) now with Chevrolet Motor Division, inventor in patent 2,779,190 for an automatic load controller.

• **Dean K. Hanink**, (*B.S. Met. E., University of Michigan, 1942*) now chief metallurgist, Metallurgical Department, Allison Division, inventor in patent 2,785,451 for forming composite articles comprising titanium or titanium-base alloys and aluminum base alloys.

• **Edward J. Martin**, (*Ph.D., Physics, University of Michigan, 1924*) head, Physics and Instrumentation Department, and **Joseph F. White**, no longer with General Motors, inventors in patent 2,786,354 for a thermal type flow meter.

• **Robert Davies**, (*Ph.D., University of Wisconsin, 1949*) assistant department head, Mechanical Development Department, and **Francis E. Heffner**, (*B.S.M.E., 1948, and M.S.M.E., Wayne State University, 1951*) senior research engineer, Mechanical Development Department, inventors in patent 2,786,363 for a torus ring for infinitely variable transmission.

• **William F. King**, (*General Motors Institute, 1940, and B.S.M.E., University of Michigan, 1941*) assistant head, Special Problems Department, inventor in patent 2,787,907 for a crankshaft balancing machine.

• **Joseph B. Bidwell**, (*B.S.M.E., Brown University, 1942*) head, Engineering Mechanics Department, inventor in patent 2,789,429 for a surface gage extension probe.

#### *Rochester Products Division Rochester, New York*

• **Joseph M. McDonnel**, (*Newark College of Engineering*) senior engineer, Engineering Department, and **Henry D. Mowers**, production engineer, Production Engineering Department, inventors in patent 2,786,455 for a fluid motor.

• **Lawrence O. Dermond**, (*Purdue University and Tri-State College*) staff engineer, Engineering Department, inventor in patent 2,789,544 for a fluid motor.

#### *Saginaw Steering Gear Division Saginaw, Michigan*

• **C. W. Lincoln**, (*B.S.M.E., University of Illinois, 1916*) technical assistant to general manager, **Philip B. Zeigler**, (*B.S.E., Purdue University, 1941*) chief engineer, Product Engineering Department, and **Joseph J. Verbrugge**, (*General Motors Institute, 1941*) senior project engineer, Prod-

uct Engineering Department, inventors in patent 2,779,199 for a windshield wiper.

• **William H. Doerfner**, general manager, inventor in patent 2,779,206 for a ball nut and screw assembly.

• **C. W. Lincoln\***, **Philip B. Zeigler\***, and **Robert M. Gold**, no longer with GM, inventors in patent 2,779,427 for a fluid power steering apparatus.

#### *GM Styling Staff Detroit, Michigan*

• **Robert F. McLean**, (*B.S.M.E., 1943 and professional degree in industrial design, California Institute of Technology*) executive in charge of styling product analysis and planning, Administration Department, inventor in patent 2,780,076 for an automobile refrigerating apparatus.

• **Glen A. Smith**, (*B.A., University of Detroit*) GM Overseas Operations Division liaison with Styling Staff, inventor in patent 2,782,062 for a door lock.

• **Louis Gelfand**, (*Wayne State University*) project engineer, Engineering Department, inventor in patent 2,790,887 for a domestic appliance.

#### *Ternstedt Division Detroit, Michigan*

• **Arthur T. Lausten**, (*B.S., Wayne State University, 1936*) senior research chemist, Process Development Department and **Grayland T. Larsen**, (*B.S.Chem.E., Michigan College of Mining and Technology, 1937*) general supervisor, Process Engineering Department, inventors in patent 2,767,359 for a high voltage current control. This is a correction of a previous listing made on page 38 of the July-August-September issue.

• **LaVerne B. Ragsdale**, (*University of Detroit, Franklin College, and B.S.M.E., Lawrence Institute of Technology, 1939*) staff engineer, Product Development Department, inventor in patent 2,779,051 for a hinge hold-open.

\*Inventors' names marked with an asterisk have biographical listings noted previously in this issue's Notes About Inventions and Inventors.

## Educational Aids Available to Educators in the Fields of Engineering and Science

For many years GM Divisions and Staffs have made available to college and university educators classroom aids in the form of booklets, charts, films, kits, manuals, displays, and equipment. A catalog, "General Motors Aids to Educators," is available which lists and describes each aid. Educators in the fields of engineering and science who wish a copy of this catalog may write to the Educational Relations Section, Public Relations Staff, GM Technical Center, P.O. Box 177, North End Station, Detroit 2, Michigan.

The classroom aids available deal with most fields of engineering and science. For example, booklets dealing with the metallurgical field describe the development, production, use, and characteristics of Armasteel castings and the wide range of present-day casting techniques. Other booklets deal with powder metallurgy, the operating principles of the Hydra-Matic automatic transmission, and factors influencing the design of railroad motive power. Engineering handbooks also are available which give design information on anti-friction bearings. Classroom charts, suitable for mounting, include the operating principles of the 2 and 4-stroke Diesel engine and typical gear combinations used in engineering design work. Other charts are available which show, by means of cut-away views, the operation of a Diesel engine.

Also available, at a special educational price, are automotive and Diesel engines, heat transfer equipment, and automatic transmissions. A teaching kit for engineering drawing educators includes actual engineering drawings with explanatory texts for use as engineering problems in the classroom. Displays also are available on a loan basis for school exhibits and teaching purposes. One such display can be used to demonstrate transistor theory.

# Determine the Horizontal and Vertical Deflection of a Circular Beam

By ROBERT W. LEWIS  
Allison Division

Assisted by John A. Straw  
General Motors Institute

The determination of the deflection of curved beams requires the application of integral calculus. Equations first must be established for the vertical and horizontal deflection. These equations then must be integrated over the length of the beam. This is the solution to the problem presented in the July-August-September 1957 issue of the GENERAL MOTORS ENGINEERING JOURNAL. The vertical deflection of the circular beam is 0.342 in. downward and the horizontal deflection is -0.107 in. to the right.

THE first step in setting up the equation for deflection of the circular curved beam is to establish the coordinate system (Fig. 1).

The problem stated that the two following equations

$$\Delta y = \int_A^B \frac{M}{EI} x \, ds \quad (2)$$

$$\Delta x = \int_A^B \frac{M}{EI} y \, ds \quad (3)$$

were to be expressed in terms of  $R$ ,  $\Theta$ , and  $d\Theta$ . By doing this, numerical values may then be substituted into each of the resulting equations to determine the required vertical and horizontal deflection of the circular curved beam.

The first step in expressing equation (2) in terms of  $R$ ,  $\Theta$ , and  $d\Theta$  is to substitute into the equation the following values for  $x$  and  $ds$ :

$$x = R \sin \Theta$$

$$ds = R \, d\Theta.$$

Equation (2) then becomes:

$$\Delta y = \int_{\Theta=0}^{\Theta=\alpha} \frac{M}{EI} R^2 \sin \Theta \, d\Theta. \quad (4)$$

Referring to the diagram for the circular beam (Fig. 1) shows that a positive  $\Delta y$  is produced by compression on the inside of the beam. The bending moment  $M$ , therefore, can be expressed as follows:

$$M = Vx - Hy$$

or

$$M = V(R \sin \Theta) - H(R - R \cos \Theta).$$

Substituting the above values for the bending moment  $M$  into equation (4) gives the following:

$$\begin{aligned} \Delta y &= \frac{1}{EI} \int_0^\alpha VR^3 \sin^2 \Theta \, d\Theta \\ &\quad - \frac{1}{EI} \int_0^\alpha HR^3 \sin \Theta \, d\Theta \\ &\quad + \frac{1}{EI} \int_0^\alpha HR^3 \sin \Theta \cos \Theta \, d\Theta. \end{aligned} \quad (5)$$

Equation (5) can now be integrated between the limits of zero and  $\alpha$  as follows:

$$\begin{aligned} \Delta y &= \frac{VR^3}{EI} \left[ \frac{\Theta}{2} - \frac{\sin 2\Theta}{4} \right]_0^\alpha \\ &\quad - \frac{1}{EI} \left[ HR^3 (-\cos \Theta) \right]_0^\alpha \\ &\quad + \frac{1}{EI} \left[ HR^3 \left( \frac{1}{2} \right) \sin^2 \Theta \right]_0^\alpha. \end{aligned} \quad (6)$$

Substituting into equation (6) the trigonometric functions of  $\sin 0^\circ = 0$  and  $\cos 0^\circ = 1$  gives the following expression for  $\Delta y$ , the vertical deflection of the curved beam:

A typical application of integral calculus

$$\begin{aligned} \Delta y &= \frac{VR^3}{EI} \left[ \frac{\alpha}{2} - \frac{1}{4} \sin 2\alpha \right] \\ &\quad + \frac{HR^3}{EI} [\cos \alpha - 1] + \frac{HR^3}{EI} \left[ \frac{\sin^2 \alpha}{2} \right]. \end{aligned} \quad (7)$$

If the values  $y = R - R \cos \Theta$  and  $ds = R d\Theta$  are substituted into equation (3) the following expression results:

$$\Delta x = \int_{\Theta=0}^{\Theta=\alpha} \frac{M}{EI} (R - R \cos \Theta) R \, d\Theta. \quad (8)$$

Referring to the diagram for the circular beam (Fig. 1) shows that a positive  $\Delta x$  is produced by compression on the outside of the beam. The bending moment  $M$ , therefore, can be expressed as follows:

$$M = Hy - Vx$$

or

$$M = H(R - R \cos \Theta) - V(R \sin \Theta).$$

Substituting the above values for the bending moment  $M$  into equation (8) gives the following relationship:

$$\begin{aligned} \Delta x &= \frac{1}{EI} \int_0^\alpha [H(R - R \cos \Theta)^2 \\ &\quad - V(R \sin \Theta)(R - R \cos \Theta)] R \, d\Theta. \end{aligned} \quad (9)$$

Equation (9) can now be integrated as follows between the limits of zero and  $\alpha$  and the values of  $\sin 0^\circ = 0$  and  $\cos 0^\circ = 1$  then substituted to give the expression for  $\Delta x$ , the horizontal deflection of the curved beam:

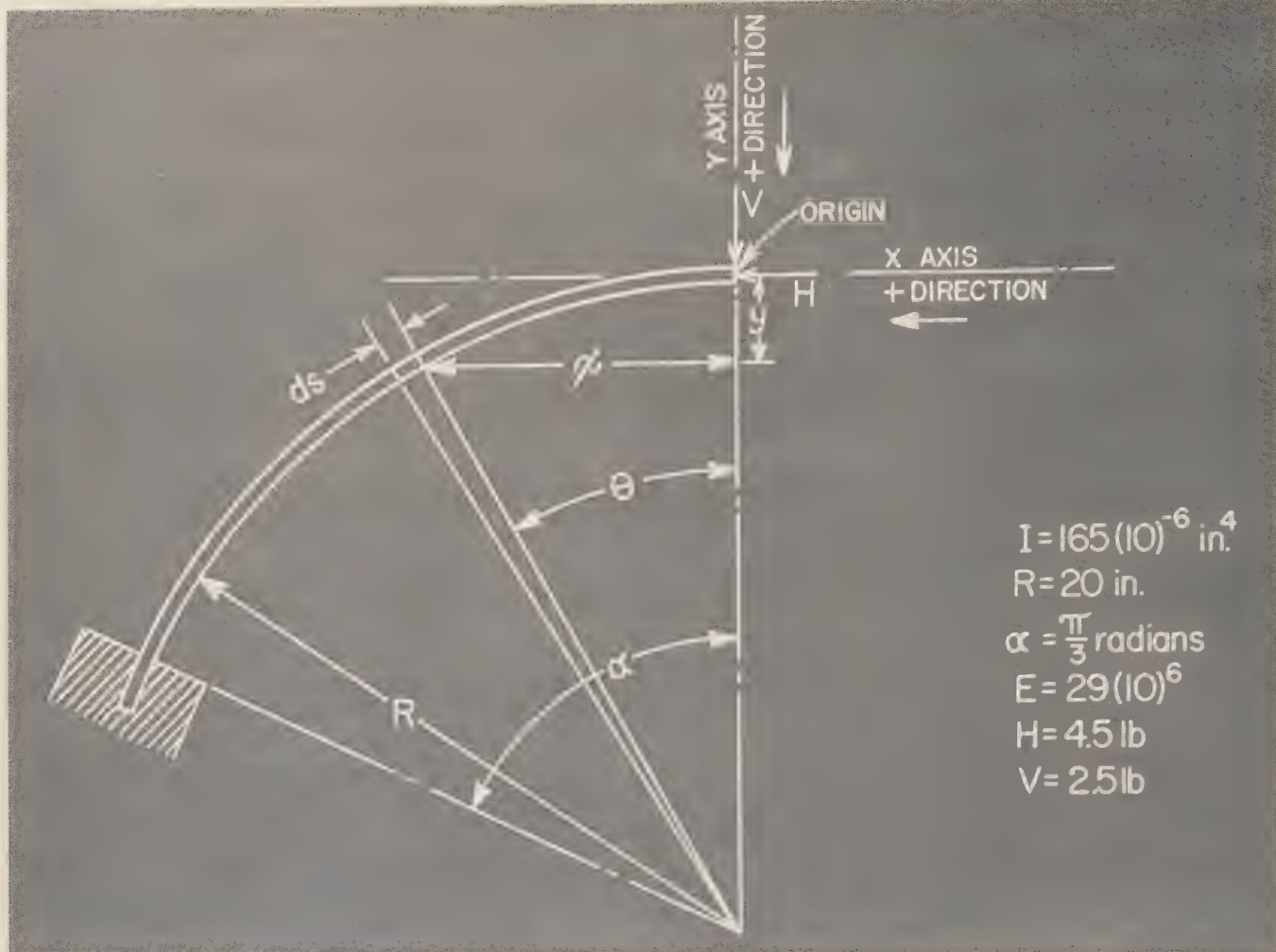


Fig. 1—In the derivation of the deflection equation for the curved beam, the origin is placed at the free end of the beam. The X and Y axes are placed as shown.

$$\Delta x = \frac{HR^3}{EI} \int_0^\alpha (1 - \cos\Theta)^2 d\Theta - \frac{VR^3}{EI} \int_0^\alpha \sin\Theta d\Theta + \frac{VR^3}{EI} \int_0^\alpha \sin\Theta \cos\Theta d\Theta \quad (10)$$

$$\Delta x = \frac{HR^3}{EI} \left[ \frac{3}{2} \Theta - 2 \sin\Theta + \frac{1}{4} \sin 2\Theta \right]_0^\alpha - \frac{VR^3}{EI} \left[ -\cos\Theta \right]_0^\alpha + \frac{VR^3}{EI} \left[ \frac{1}{2} \sin^2\Theta \right]_0^\alpha \quad (11)$$

$$\Delta x = \frac{HR^3}{EI} \left[ \frac{3}{2} \alpha - 2 \sin\alpha + \frac{1}{4} \sin 2\alpha \right] + \frac{VR^3}{EI} [\cos\alpha - 1] + \frac{VR^3}{EI} \left[ \frac{1}{2} \sin^2\alpha \right] \quad (12)$$

To determine the vertical and horizontal deflection, the numerical values for  $V$ ,  $H$ ,  $E$ ,  $I$ ,  $R$ , and  $\alpha$  (Fig. 1) are substituted into equations (7) and (12) as follows:

$$\Delta y = \frac{2.5 (20)^3}{29(10)^6 (165) 10^{-6}} \left[ \frac{\pi}{6} - \frac{1}{4} \sin \frac{2}{3} \pi \right] + \frac{4.5 (20)^3}{29 (165)} \left[ \cos \frac{\pi}{3} - 1 + \frac{\sin^2 \frac{\pi}{3}}{2} \right]$$

$\Delta y = 0.342 \text{ in.}$  deflection downward.

$$\Delta x = \frac{4.5 (20)^3}{29(165)} \left[ \frac{\pi}{2} - 2 \sin \frac{\pi}{3} + \frac{1}{4} \sin \frac{2}{3} \pi \right] + \frac{2.5 (20)^3}{29(165)} \left[ \cos \frac{\pi}{3} - 1 + \frac{1}{2} \sin^2 \frac{\pi}{3} \right]$$

$\Delta x = -0.107 \text{ in.}$  deflection to the right.

The basic equations (2) and (3), and equation (1) for angular deflection given in the statement to the problem, are not limited to cantilever beams. They also may be used for arches:

#### Bibliography

Other related literature in this field includes the following:  
 CAUGHEY, ROBERT A., *Reinforced Concrete* (New York: D. Van Nostrand Company, Inc., 1949, Fifth Edition), pp. 112-113.

# Determine the Center of Gravity Location of a Passenger Car

*Faculty Member-in-Charge:*

STEVE CENKO

*G.M.I. Cooperative Students:*

ROBERT H. BORCHERTS

Cadillac Motor Car Division

and RONALD J. SWANSON

Chevrolet Motor Division

An important aspect in the design of a passenger car is the location of its center of gravity. It is important that engineers know a car's center of gravity as its location affects ride and handling characteristics. To determine the location of the center of gravity in an irregular shaped mass such as a passenger car by strictly analytical means would entail determining the centroid location of all components of the mass. This, of course, would require tedious and time consuming calculations. Laboratory methods are available, however, for determining experimentally the height of the center of gravity above the ground level. One such method involves recording the angles of tilt of the car when it is balanced in two positions on a knife edge.

A TYPICAL problem encountered in the design of a passenger car is the determination of its center of gravity location. The location of the center of gravity is of importance to automotive engineers because it has a direct effect upon riding qualities, as well as ease of steering and handling. The center of gravity must be specified as to its location in the longitudinal and lateral directions as well as to its height relative to ground level.

The location of the center of gravity in the fore and aft direction can be found by measuring the scale loading at each wheel and then taking a summation of moments about either the front or rear wheels. In a similar manner, the location of the center of gravity in the lateral direction can be determined by taking a summation of moments about either the right or left wheels of the car.

The height of the center of gravity above the ground can be located experimentally by the following three methods:

- By using the car as a pendulum in a swing to determine first the moment of inertia and then the center of gravity<sup>1</sup> (Fig. 1a)
- By recording the change in loading on the wheels when either the rear end or the front end of the car is raised (Fig. 1b)
- By recording the angles of tilt of the car when it is balanced in two positions over a knife edge (Fig. 1c).

In the General Motors Institute mechanical engineering laboratory, the height of the center of gravity above the ground is determined by method (c). A knife edge test fixture (Fig. 2), constructed of two angle irons welded to a steel plate, is used. The fixture is bolted to the frame of the car so that a previously calculated longitudinal center of gravity is located between the knife edges. With the car elevated above the ground and resting on the knife edges, the two balance, or null, points are established. Each null point is the position of the car on the knife edge where no force is necessary to prevent the vehicle from rotating.

Before the knife edge test fixture is clamped to the frame of a car, the front and rear suspensions are locked in place. This prevents the unsprung weight from hanging loose while the car is elevated and influencing the center of gravity location. While a car is undergoing an analysis for its center of gravity location, the weight of the test fixture is assumed to be negligible. Also, the shifting of engine coolant, oil, and gasoline are assumed to have no influence on the location of the center of gravity.

## Problem

A passenger car with a wheelbase of 122 in. and a wheel tread of 59.25 in. had the following scale load readings:

Right front wheel = 1,128 lb  
Right rear wheel = 984 lb  
Left front wheel = 1,195 lb  
Left rear wheel = 993 lb.

A laboratory method:

tilt the car

on a knife edge

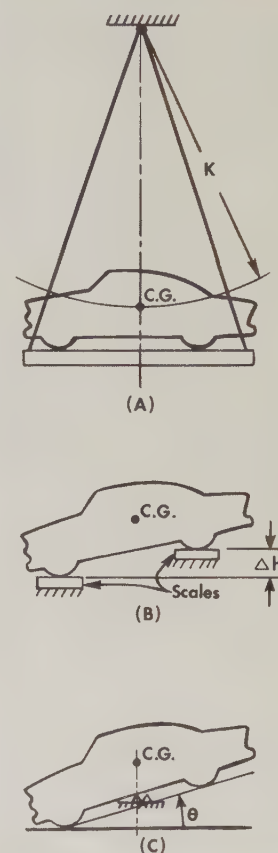


Fig. 1—Three methods are available for determining the height of the center of gravity of a passenger car above ground level. One method entails the use of a pendulum (a). By determining the moment of inertia from the period of a pendulum, the distance  $K$  can be calculated from the relationship  $I = mK^2$ . A second method for determining the height of the center of gravity (b) makes use of information recorded when a given change in height,  $\Delta h$ , causes a specific change in scale loading. In this method, both forward and rearward tipping must be done. A third method, and the one used in the mechanical engineering laboratory at General Motors Institute, requires balancing the car over a knife edge in two positions (c) and determining the angle of tilt  $\theta$  for each position. The location of the center of gravity is determined at the intersection of the vertical lines above each balance point.

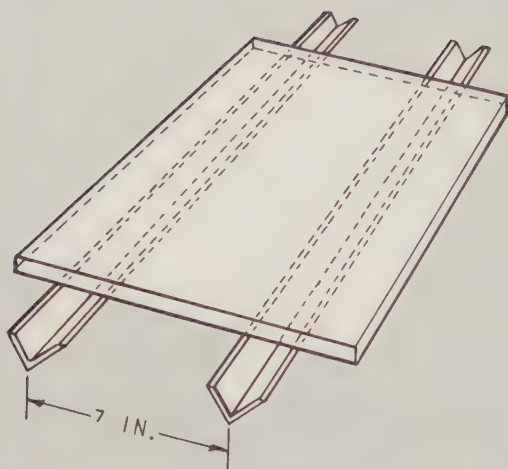


Fig. 2—To determine the location of the center of gravity of a passenger car above the ground level, a knife edge test fixture is used consisting of two angle irons welded to a steel plate. The fixture is bolted to the frame of the car.

When the knife edge test fixture was bolted to the frame of the car, prior to its being elevated, the distance from the knife edges to the ground level was measured to be 4.50 in. The distance between the knife edges was measured as 7.00 in. (Fig. 2).

To establish the balance, or null, points the car was first elevated above the ground level and then tipped forward and balanced on the front knife edge (Fig. 3a). With the car in this position, the following dimensions were recorded for the front null point:

distance from reference surface to center of front wheel = 19.69 in.

distance from reference surface to center of rear wheel = 42.62 in.

The car was then tipped rearward (Fig. 3b) and the following dimensions were taken to establish the rear null point:

distance from reference surface to center of front wheel = 42.81 in.

distance from reference surface to center of rear wheel = 15.50 in.

Using the established information, the problem is to calculate the longitudinal center of gravity, the lateral center of gravity, and the height of the center of gravity above ground level of the passenger car. The solution to the problem will appear in the January-February-March 1958 issue of the *GENERAL MOTORS ENGINEERING JOURNAL*.

#### Bibliography

1. BRINK, REO S., "A Method for Determining the Center of Gravity and Moment of Inertia of an Automobile," *General Motors Engineering Journal*, Vol. 1, No. 2 (September-October 1953), pp. 60-61.

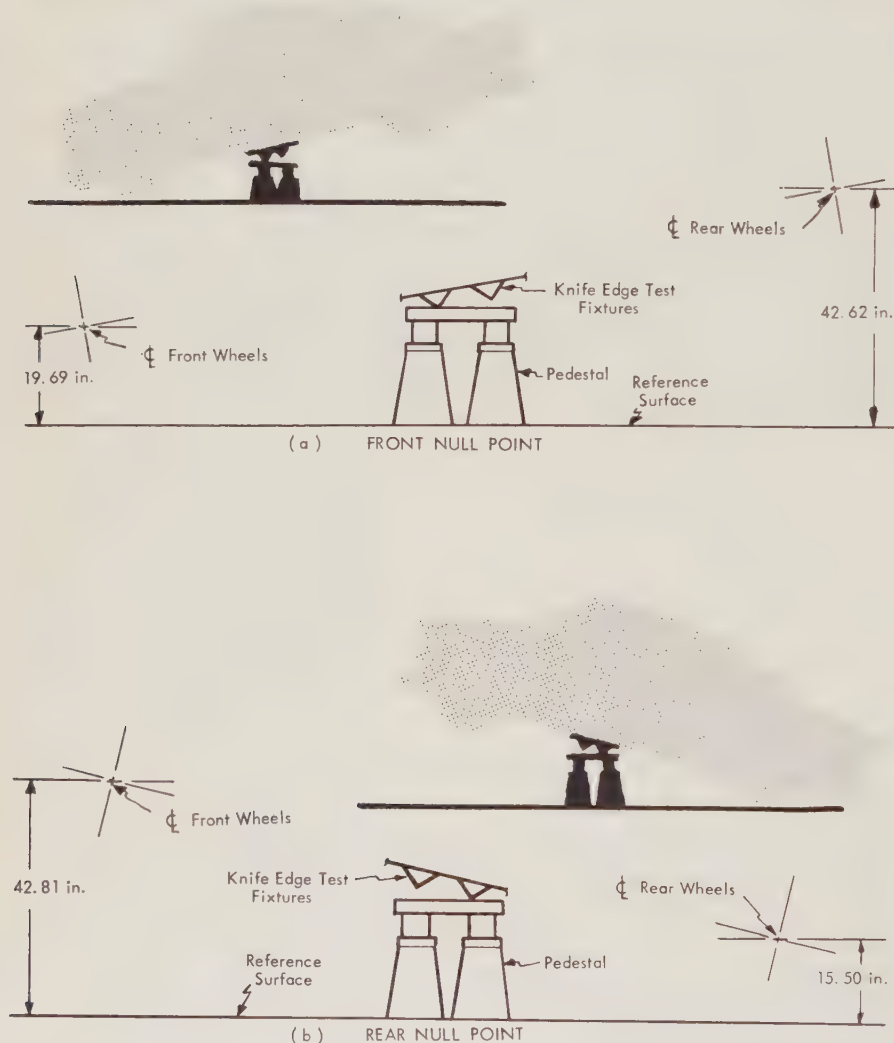


Fig. 3—To establish the height of the center of gravity above ground level requires the determination of the two balance, or null, points. A front null point (a) and a rear null point (b) are determined by measuring the distance from a reference surface to the center of the wheels in each balance position.

The problem presented here is typical of problems initiated and solved by students enrolled in advanced laboratory course work at General Motors Institute. This particular problem was solved during an Automotive Chassis—Design and Testing Laboratory period. The problem allowed the students to devote time to actual engineering test and analysis, in a manner similar to that encountered in an engineering department.

## Solution to the Previous Problem:

# Determine the Design Specifications for a Crank and Connecting Rod Transfer Mechanism

By PHILIP WEST and  
WALTER D. NOON\*  
General Motors Process  
Development Staff

Assisted by Gerhard W. Sood  
General Motors Institute

In-line types of automatic assembly machines having a relatively short index movement and light loads to transfer generally use a cam-controlled transfer mechanism. Such a mechanism could not be used on the in-line machine designed and developed by GM Process Development Staff engineers for the automatic assembly of automotive cylinder heads. The specifications called for the indexing of an 11,000-lb load a distance of 24 in. in a time of 1.4 seconds. A crank and connecting rod transfer mechanism was selected to accomplish the index movement required. Prior to the design of the components of the mechanism, however, a detailed analysis of the horsepower required to effect the transfer and the forces developed during the transfer was required. This is the solution to the problem presented in the July-August-September 1957 issue of the *GENERAL MOTORS ENGINEERING JOURNAL*. The maximum horsepower required at the crank was calculated to be 11.6 hp and the maximum torque developed at the crank was calculated to be 2,840 lb-ft. During transfer of the load the maximum forces developed were calculated to be 3,530 lb along the connecting rod, 3,425 lb at the wrist pin in the direction of travel, and 1,040 lb at the wrist pin normal to the direction of travel.

SINCE it appeared that the crank and connecting rod transfer mechanism could be used for future designs, it was decided to set the problem up for solution on an analog computer. This would make it possible to evaluate various loads, index times and distances, crank to connecting rod ratios, and coefficients of friction in a minimum of time. The mathematical calculations presented are those used in setting up this problem for solution on an analog computer.

The first step in the solution to the problem is to express  $S$ , the distance between the center of crank arm rotation and the wrist pin (Fig. 1), in terms of  $r$ ,  $l$ , and  $\Theta$ . This can be done by using the law of cosines as follows:

$$l^2 = r^2 + S^2 - 2rS(\cos \Theta) \quad (1)$$

where

- $l$  = length of the connecting rod (3 ft)
- $r$  = length of the crank arm (1 ft)
- $\Theta$  = angle between the crank arm and  $S$ .

Solving equation (1) for  $S$  gives the following:

$$S = r \left( \cos \Theta + \left[ \frac{l^2}{r^2} - \sin^2 \Theta \right]^{1/2} \right). \quad (2)$$

Equation (2) may be differentiated with respect to time  $t$  to obtain an expression for the load velocity as follows:

$$\frac{dS}{dt} = r \left( -\sin \Theta \frac{d\Theta}{dt} - \sin \Theta \cos \Theta \frac{d\Theta}{dt} \left[ \frac{l^2}{r^2} - \sin^2 \Theta \right]^{-1/2} \right) \quad (3)$$

where

$$\frac{dS}{dt} = \text{load velocity.}$$

A negative torque was among the conditions detected in a complete analysis

Differentiating equation (3) with respect to time  $t$  gives the load acceleration as follows:

$$\begin{aligned} \frac{d^2S}{dt^2} = r \left\{ - \left( \frac{d\Theta}{dt} \right)^2 \cos \Theta \right. \\ + \left( \frac{d\Theta}{dt} \right)^2 \sin^2 \Theta \left[ \frac{l^2}{r^2} - \sin^2 \Theta \right]^{1/2} \\ - \left( \frac{d\Theta}{dt} \right)^2 \cos^2 \Theta \left[ \frac{l^2}{r^2} - \sin^2 \Theta \right]^{1/2} \\ - \left( \frac{d\Theta}{dt} \right)^2 \sin^2 \Theta \cos^2 \Theta \left[ \frac{l^2}{r^2} - \sin^2 \Theta \right]^{-3/2} \left. \right\}. \quad (4) \end{aligned}$$

where

$$\frac{d^2S}{dt^2} = \text{load acceleration}$$

$$\frac{d^2\Theta}{dt^2} = 0.$$

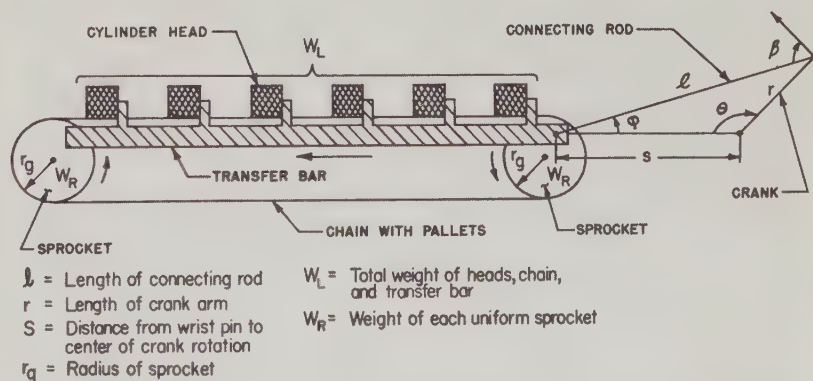


Fig. 1—This schematic diagram illustrates the connecting rod and crank transfer mechanism.

\*For Mr. Noon's biography and photograph, please see p. 63 of the April-May-June 1957 *GENERAL MOTORS ENGINEERING JOURNAL*. This is the second paper contributed by Mr. Noon, project engineer in the Electronics Department of the Process Development Staff.

The time required to move the load was specified as 1.4 seconds. During this time the angle  $\Theta$  varies from  $\pi$  to zero radians. The angular velocity of the crank arm, therefore, can be given by the following equation:

$$\frac{d\Theta}{dt} = \frac{\pi}{1.4}$$

where

$$\frac{d\Theta}{dt} = \text{angular velocity of crank arm}$$

$$\frac{d\Theta}{dt} = 2.25 \text{ radians per second.}$$

Substituting the values for  $l$ ,  $r$ , and  $\frac{d\Theta}{dt}$  into equation (4) gives an equation which expresses the load acceleration in terms of  $\Theta$ . This equation can then be solved for values of  $\Theta$  equals  $180^\circ$ ,  $150^\circ$ ,  $135^\circ$ ,  $120^\circ$ ,  $90^\circ$ ,  $60^\circ$ ,  $30^\circ$ , and  $0^\circ$ . A curve can then be plotted (Fig. 2) which shows the load acceleration versus degrees of crank rotation.

The effective mass of each uniform sprocket can be expressed as follows:

$$M_R = \frac{W_R}{32.2} \left( \frac{R^2}{r_g^2} \right) \quad (5)$$

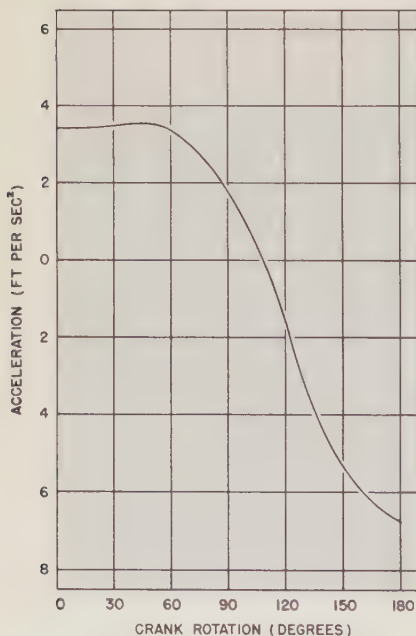


Fig. 2—This curve indicates the load acceleration versus degrees of crank rotation.

where

$M_R$  = effective mass of each uniform sprocket (slugs)

$W_R$  = weight of each uniform sprocket (lb)

$R$  = radius of gyration (ft)

$r_g$  = radius of the sprocket (ft).

Solving equation (5) gives the following value for the effective mass of each uniform sprocket:

$$M_R = \frac{W_R}{32.2} \left( \frac{r_g^2}{\sqrt{2}} \right)^2$$

$$M_R = \frac{114}{2(32.2)} = 1.77 \text{ slugs.}$$

The mass of the load moving linearly can be expressed as follows:

$$M_L = \frac{W_L}{32.2} = \frac{11,000}{32.2} = 342 \text{ slugs}$$

where

$M_L$  = mass of load moving linearly (slugs)

$W_L$  = weight of load moving linearly (lb).

The total effective mass  $M$  is equal to the mass of the load moving linearly plus the effective mass of the two sprockets. Therefore,

$$M = 342 + 2(1.77) \doteq 346 \text{ slugs.}$$

The frictional force  $F_f$  opposing the load motion can be expressed as follows:

$$F_f = 11,000(0.2) = 2,200 \text{ lb.}$$

The total force  $F_l$  acting along the direction of the load motion can be expressed by the following equation:

$$F_l = F_f + M \frac{d^2S}{dt^2} \text{ (lb)}$$

$$F_l = 2,200 + 346 \frac{d^2S}{dt^2} \text{ (lb).}$$

The following equations can now be written for the total force  $F_l$  acting along the connecting rod, the force  $F_d$  acting downward at the wrist pin, and the torque  $T$  in lb-ft which must be applied to the crank arm.

$$F_l = \frac{F_l}{\cos \phi} \text{ (lb)}$$

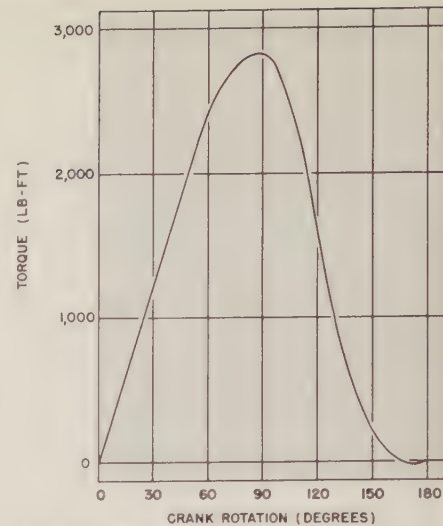


Fig. 3—Shown here is a curve for the torque required at the crank versus degrees of crank rotation. The curve indicates that a negative torque is required to move the load at the end of the transfer.

$F_d = F_l \tan \phi$  (Since the coefficient of friction is conservative, the additional friction load imposed by the downward force is neglected)

$$T = r F_l (\cos \beta) = \frac{r F_l}{\cos \phi} (\cos \beta).$$

The angle  $\beta$  can be calculated as follows:

$$\beta = 90^\circ - (180^\circ - \Theta - \phi) = \Theta + \phi - 90^\circ.$$

The term  $\cos(\Theta - \phi + 90^\circ)$  is equal to  $\sin(\Theta - \phi)$ . The torque  $T$ , therefore, which must be applied to the crank arm can be expressed as follows:

$$T = \frac{r F_l}{\cos \phi} \sin(\Theta + \phi).$$

The sine of angle  $\phi$  can be stated as:

$$\sin \phi = \frac{r (\sin \Theta)}{l}.$$

The cosine of angle  $\phi$  can be stated as:

$$\cos \phi = \sqrt{1 - \frac{r^2}{l^2} (\sin^2 \Theta)}$$

$$\cos \phi = \sqrt{1 - \frac{\sin^2 \Theta}{9}}.$$

The horsepower (hp) required at the crank can be expressed as follows:

$$\text{hp} = \frac{T \frac{d\Theta}{dt}}{550}.$$

The force acting along the direction of load motion ( $F_t$ ) and the angle  $\phi$  can now be calculated as functions of  $\Theta$ . This calculation, in turn, allows the forces  $F_t$  and  $F_d$ , and the torque  $T$  and horsepower  $hp$  to be calculated as functions of  $\Theta$ .

The design requirements of the crank and connecting rod mechanism can now be completed based on the predicted values for  $F_t$ ,  $F_l$ ,  $F_d$ ,  $T$ , and  $hp$ . A torque curve can be drawn (Fig. 3) showing the required crank torque as a function of degrees of crank rotation. Similar curves could also be drawn for the other quantities.

The maximum values for  $hp$ ,  $T$ ,  $F_t$ ,  $F_l$ , and  $F_d$  are as follows:

Maximum horsepower (hp) required at the crank	= 11.6 hp
Maximum torque $T$ developed at the crank	= 2,840 lb-ft
Maximum force $F_t$ along the connecting rod	= 3,530 lb
Maximum force $F_l$ along the direction of travel	= 3,425 lb
Maximum force $F_d$ normal to the direction of travel	= 1,040 lb.

It should be noted that since a limited number of points are calculated and slide rule inaccuracy is involved, values slightly different from those listed above could be obtained.

### Summary

This problem is intended to illustrate the value of analysis in the solution of engineering problems. It is often possible to make broad assumptions and obtain approximate solutions to such problems. A complete analysis of the problem, however, often provides the engineer with valuable design data. For example, if the torque curve (Fig. 3) is examined closely it will be noted that a negative torque is required to move the load at the end of the transfer. If the load is being pushed by the crank motion—that is, the crank cannot pull on the load to stop it—the negative torque cannot be applied and the load will slide a small distance beyond the point of intended load position. An analysis such as this helps the engineer to take corrective design measures before the system is built.

## A Typical Problem in Engineering:

### Determine the Operating Characteristics of a Drive and Control System for a Transfer Mechanism

By PHILIP WEST and  
WALTER D. NOON  
General Motors Process  
Development Staff

Assisted by Gerhard W. Sood  
General Motors Institute

The recent completion of an automatic assembly machine by engineers of the General Motors Process Development Staff (located at the GM Technical Center) posed two major design problems. The first problem involved the design of a transfer mechanism to move the load a controlled distance in a minimum of time and in a smooth, accurate, and reliable manner. This problem was solved satisfactorily through the use of a crank and connecting rod mechanism.\* The second problem, and the one presented here, involved the analysis of a system to power and control the transfer mechanism. An electric motor was selected as the most practical source of power. Two conventional truck clutches, one used as a clutch and one used as a brake, were selected for obtaining starting and stopping control. Before the contemplated power and control system could become a part of the assembly machine, however, it was necessary to predict what the operating characteristics of the drive unit would be.

THE overall design of an automatic assembly machine requires consideration of two major factors: (a) the design of a transfer mechanism to move the work from station to station and (b) the design of a unit to drive and control the transfer mechanism. An automatic assembly machine recently designed by GM Process Development Staff engineers to assemble automotive cylinder heads, used a crank and connecting rod as the transfer mechanism. To actuate the crank an electric motor driving a speed reducer was decided upon, since this would provide a low maintenance, trouble-free method for providing power.

The selection of the motor and speed reducer to power the crank left one more item to be decided upon—how should the transfer mechanism be controlled? Should the motor be started and stopped each time the work was indexed from station to station or should the speed reducer be engaged and disengaged from the motor? Because of the frequency of stops, the inertias involved, and the accuracy required by the indexing motion, control of the transfer mechanism by starting and stopping the motor for each indexing motion would be impractical. It was

decided, therefore, to use a clutch and brake arrangement. Such an arrangement would start and stop the speed reducer while allowing the motor to run continuously.

Major requirements in the selection of a method to control the transfer mechanism were reliability, availability, and cost. Two conventional truck clutches, one used as a clutch and one as a brake, would meet these requirements. But how would the clutches perform in this unusual application? To answer this question it was necessary to calculate the heat generated at the clutch facing as an indication of clutch life. This would determine whether or not it could do the job required. The brake performance requirements would be less than those of the clutch. Therefore, no heat calculations would be required for the brake.

### Design Information and Specifications

The arrangement of the drive and control system had the clutch and brake mounted between the motor and speed reducer (Fig. 1). A 20 hp, 1,800 rpm, Design B electric motor was selected to drive a double worm gear speed reducer having a gear reduction ratio of 102 to 1.

Preliminary calculations by Process Development Staff engineers plus specifications provided by the motor and speed reducer suppliers established the

\*This problem, entitled "Determine the Design Specifications for a Crank and Connecting Rod Transfer Mechanism," was presented on pp. 51-2 of the July-August-September 1957 issue of the GENERAL MOTORS ENGINEERING JOURNAL. For the solution to the problem please see pp. 47-8 of this issue.

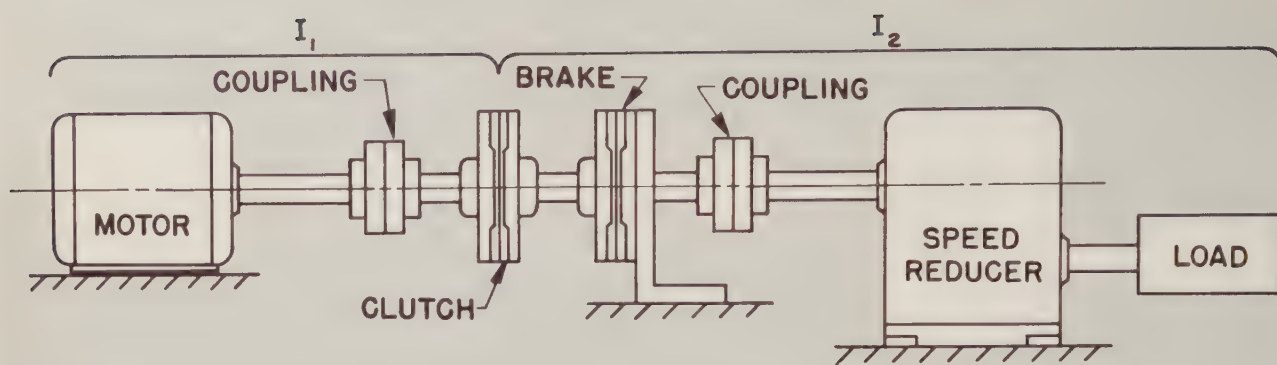


Fig. 1—Shown here is a schematic representation of the arrangement used to drive and control the transfer mechanism for an automatic assembly machine. A clutch and brake unit allowed the speed reducer to be started and stopped

without interfering with the continuous operation of the motor. In the diagram,  $I_1$  and  $I_2$  are the effective inertias of the masses attached to the clutch input and clutch output shafts respectively.

following information for each of the components comprising the drive and control system.

#### Motor

- Rotary moment of inertia = 0.178 slug-ft<sup>2</sup>
- Average torque of the motor in the operating speed range expected = 60 lb-ft
- Motor must not slow down below 1,440 rpm
- Speed of motor at the time of clutch engagement will be 1,790 rpm
- Speed of motor under load (when driving the speed reducer) will recover to 1,750 rpm after slowing down because of initial clutch engagement.

#### Speed Reducer

- Rotary moment of inertia at the reducer input shaft = 0.01 slug-ft<sup>2</sup>
- Efficiency = 81 per cent.

#### Clutch and Brake

- Assume constant clutch capacity of 300 lb-ft
- Rotary moment of inertia of clutch section attached directly to output shaft of motor = 0.375 slug-ft<sup>2</sup>
- Rotary moment of inertia of both the clutch disc and brake disc attached to input shaft of speed reducer = 0.013 slug-ft<sup>2</sup>.

#### Load

- Effective load inertia at output shaft of speed reducer = 20.8 slug-ft<sup>2</sup>
- Effective load inertia must be reflected back to the input shaft of the speed reducer. When making this computation, the square of the gear reduction ratio should be used.

#### Coupling

- Rotary moment of inertia of constantly rotating coupling between the motor and clutch = 0.007 slug-ft<sup>2</sup>
- Rotary moment of inertia of normally stationary coupling between clutch and speed reducer = 0.006 slug-ft<sup>2</sup>

- Rotary moment of inertia of shaft to be ignored.

#### Problem

The problem is to determine the following operating characteristics of the drive and control system:

- Minimum motor speed which results when the clutch is engaged
- Number of revolutions of slip in the clutch upon engagement
- The index time lost because of the time required to accelerate the reducer input shaft from 0 rpm to 1,750 rpm as compared to a reducer input shaft constantly rotating at 1,750 rpm
- Amount of rotation of the output shaft of the speed reducer before the motor regains speed of 1,750 rpm
- Heat generated at the face of the clutch.

The solution to the problem will be presented in the January-February-March 1958 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

# Technical Presentations by GM Engineers

The technical presentation is another way in which information about current engineering and scientific developments in General Motors can be made available to the public. A listing of speaking appearances by General Motors engineers, such as that given below, usually includes the presentation of papers before professional societies, lecturing to college engineering classes or student societies, and speaking to civic or governmental organizations. Educators who wish assistance in obtaining the services of GM engineers to speak to student groups may write to the Educational Relations Section, Public Relations Staff, General Motors Technical Center, P. O. Box 177, North End Station, Detroit 2, Michigan.

GM personnel who have made recent presentations are as follows:

## Automotive Engineering

**George W. Jackson**, engineering manager, automotive products, Engineering Department, Delco Products Division, before senior mechanical engineering students of North Dakota State College, Fargo, April 22; title: Automotive Ride Control Engineering.

**James J. Hovorka**, project engineer, brake section, Engineering Department, Moraine Products Division, before the Purdue Student Chapter of the Society of Automotive Engineers, Purdue University, May 2; title: Vehicle Safety and Crash Investigation.

**Robert R. Mandy**, supervising engineer, air conditioning section, Engineering Department, Harrison Radiator Division, before the Wichita Chapter of the American Society of Refrigerating Engineers, Wichita, Kansas, May 21; title: Future Trends in Automotive Air Conditioning.

**George P. Ransom**, section engineer, Power Development Section, GM Engineering Staff, before the annual meeting of National Tank Truck Carriers, Detroit, May 29; title: The Case for Fuel Injection.

**George A. Brown**, field contact engineer, Spark Plug Engineering Department, AC Spark Plug Division, before a group of service managers and garage operators, Pittsburgh, June 5; title: Spark Plug Problems and Proper Shop Procedures.

**Dale B. McCormick**, section engineer, Automotive Ordnance Section, GM Engineering Staff, before the annual

meeting of the Combat and Tactical Vehicle Division, American Ordnance Association, Fort Knox, Kentucky, June 17-18; title: Research and Development of Band Tracks.

**Henry S. Smith**, administrative engineer, Product Engineering Department, Saginaw Steering Gear Division, before the summer session on steering suspension, Ferris Institute, Big Rapids, Michigan, July 16 and August 6; title: Automotive Steering and Service.

**Howard H. Dietrich**, Research and Development Department, Rochester Products Division, before the S.A.E. west coast meeting, Seattle, Washington, August 16; title: Automotive Exhaust Hydrocarbon Reduction During Deceleration by Induction System Devices.

## S.A.E. Summer Meeting Atlantic City, New Jersey

The following GM personnel made technical presentations at the S.A.E. annual summer meeting, Atlantic City, June 2 to 7:

**John D. Caplan**, assistant head, Fuels and Lubricants Department, Research Staff, and **Charles J. Brady**, GM Proving Ground; title: Vapor Locking Tendencies of Fuels—a Practical Approach. **John G. Haviland**, senior project engineer, Experimental and Development Department, Fisher Body Division; title: New Materials Needed for Automobile Seats. **G. M. Haviland**, senior engineer-in-charge, Trim and Hardware Styling, Fisher Body Division; title: Aluminum Usage—as Analyzed by the Automotive Engineer. **Hugh W. Larsen**, senior project engineer, Noise and Vibration

Laboratory, GM Proving Ground; title: Instrument Applications to Riding Comfort. **Alex C. Miar**, staff engineer, truck chassis, Engineering Department, Chevrolet Motor Division; title: Road Behavior of a Modern Truck. **Lloyd E. Muller**, staff engineer, chassis engineering, Buick Motor Division; title: Dynamics of a Low Silhouette Torque Tube Drive Line. **Shirrell C. Richey**, staff engineer, Chevrolet Motor Division; title: A Carriage for Milady. **Frank W. Sinks**, application engineer, Product Application Group, Detroit Diesel Engine Division; title: Matching the Engines to the Applications. **William A. Turunen**, head, Gas Turbines Department, GM Research Staff, **Robert Shilling**, chief engineer, Research and Development Department, Chevrolet Motor Division, and **E. L. Baugh**, Cadillac Motor Car Division; title: Aspects of the Automotive Gas Turbine for Military and Commercial Vehicles.

## Bearings

**Robert J. Valentine**, project engineer, aircraft section, Engineering Department, New Departure Division, before engineers of the Hamilton Standard Division, United Aircraft Corporation, Windsor Locks, Connecticut, May 27; title: Design of Small High Speed Bearings.

**Peter J. Baker**, project engineer, aircraft section, Engineering Department, New Departure Division, before engineers of the Hamilton Standard Division, United Aircraft Corporation, Windsor Locks, Connecticut, June 3; title: Laboratory Testing of Small High Speed Bearings.

**L. D. Cobb**, manager, research and development, Product Engineering Department, New Departure Division, before engineers of the Sunstrand Machine Tool Company, Rockford, Illinois, June 5; title: High Speed-High Temperature Bearings.

## Electrical Engineering

**Robert W. Leland**, manager, electrical engineering, Engineering Department, Delco Products Division, before the American Institute of Electrical Engineers, Dayton, Ohio, April 10; panel

member on research development on motors.

**Shields Baker**, project engineer, Electronic Development Department, AC Spark Plug Division, before the Saginaw Valley Instrumentation Engineers, General Motors Institute, Flint, May 13; title: Universal Automatic Test Fixture for Electronic Units.

**Brooks Short**, supervisor, engineering research, Engineering Department, Delco Remy Division, before the Kiwanis Club, Anderson, Indiana, May 21; title: Ham Broadcasting, and before the Indiana Chapter of the Association of Police Communications Officers, Indianapolis, June 20; title: The Present Status of Vehicular Radio Interference Problems.

## Foundry

**T. E. Smith, III**, general superintendent, Central Foundry Division, before the Central Indiana Section of the American Foundrymen's Society, Indianapolis, April 1; title: Control of Quality.

**C. E. Drury**, plant manager, Danville, Illinois Plant of Central Foundry Division, before the Central Indiana section of the American Foundrymen's Society, Indianapolis, May 13; title: Gating to Control Pouring Rate and the Effect on the Casting.

## Manufacturing

**E. R. Clark**, supervisor, quality control, Inspection Department, Detroit Transmission Division, before the 11th annual convention of the American Society for Quality Control, Detroit, May 24; title: AQL's Are Half the Story, and before the Quality Standards Sub-Committee Convention, Rochester, New York, June 6; title: The Quality Manager and Quality Costs.

**E. D. Ditto**, assistant master mechanic, Master Mechanics Department, Detroit Transmission Division, before the Society for the Advancement of Management, New York City, June 13; title: Organizing for Integrated Handling Systems.

**E. G. Lommel**, plant engineer, Plant Engineering Department, Detroit Transmission Division, before the General Motors Institute Technical Club, Plymouth, Michigan, July 9; title: What is a Plant Engineer?

## Metallurgy

**Kenneth B. Valentine**, metallurgist-engineer, Engineering Department, Pontiac Motor Division, before the Research Committee, American Iron and Steel Institute, Detroit, June 25; title: Materials Comparative with Steel.

**Charles E. Norton**, manager, chemical section, Chemical Laboratory, Engineering Department, New Departure Division, before the Allegheny Ludlum Steel Company, Watervliet, New York, July 16; title: Vacuum Melted Steels.

## Research

**Carl J. Leistner**, senior experimental chemist, metallurgical department, Allison Division, before the Eighth Annual Symposium on Spectroscopy, Chicago, April 30; title: An Arc Method for Sample Transfer in Spectrochemical Analysis.

**Alexander Somerville**, supervisor, radioisotope laboratory, Physics and Instrumentation Department, GM Research Staff, before the Michigan Sewage and Industrial Wastes Association, Traverse City, May 21; title: The Control of Radioactive Wastes.

**Robert C. Frank** and **E. Donald Swets**, research physicists, Physics and Instrumentation Department, GM Research Staff, before the American Society for Testing Materials Committee E-14 on Mass Spectrometry, New York City, May 24; title: Mass Spectrometer Studies of Hydrogen Permeation Through Steel.

Before the American Nuclear Society, Pittsburgh, June 10 to 12, GM Research Staff Physics and Instrumentation Department speakers: **Farno L. Green**, senior research physicist, and **James J. Gumbleton**, now in military service; title: Transient Piston Ring Wear in Automotive Engines Using FE-59. **John P. Danforth**, senior research engineer, and **Alfred J. Williams, Jr.**, GM Process Development Staff; title: Radioactive W<sup>187</sup> for Carbide Machining Tool Evaluation of Production Type Equipment. **Farno L. Green** and **Alexander Somerville**, supervisor, radioisotope laboratory; title: Continuous Counting of Gamma Rays From Hot Radioactive Liquids. **William J. Mayer**, senior research chemist; title: Prepara-

tion of Counting Standards for Wear Studies Using Radioactive Fe and Sintered WC.

Before the 6th Annual Conference on Industrial Applications of X-Ray Analysis, Denver, Colorado, August 7, GM Research Staff Physics and Instrumentation Department speakers: **Donald P. Koistinen**, research physicist, **Richard E. Marburger**, research physicist, and **Richard P. Mitchell**, assistant technician; title: A Simplified Procedure for Calculating Peak Position in X-Ray Residual Stress Measurement on Hardened Steel. **Richard E. Marburger**, and **Donald P. Koistinen**; title: Effect of Penetration on Quantitative X-Ray Diffraction Measurements.

**Ronald L. Scott**, junior chemist, Physics and Instrumentation Department, GM Research Staff and **Anna Turkelo** (Research Laboratory, General Electric Company), before the American Society for Testing Metals, Atlantic City, June 18; title: The Two-Stage Carbon Replica for Electron Metallography.

## Miscellaneous Subjects

**George A. Neyhouse**, supervisor, engineering, and **Edward J. Bentley**, supervisor, technical employment, Engineering Employment Department, Delco Products Division, before the American Institute of Electrical Engineers, Tennessee Polytechnic Institute, Cookeville, May 3; title: Value of Summer Employment for Engineering Students.

**David C. Apps**, head, Noise and Vibration Laboratory, GM Proving Ground, before Detroit Math Club, GM Technical Center, May 16; title: Mathematics in Industry.

**Helen B. Barlett**, supervisor, ceramic research, Research Department, AC Spark Plug Division, before the Rock and Mineral Club, Flint Junior College, May 16; title: Gems—Natural and Synthetic.

**Howard Vogel**, section engineer, spark plug engineering, AC Spark Plug Division, before Airlines Personnel, Kansas City, Kansas, May 21, and Tulsa, Oklahoma, May 23; title: Aviation Clinic.

**Donald E. Hart**, assistant head, Special Problems Department, GM Research Staff, before the American Society for Quality Control, Detroit, May 22 to 24; title: The Digital Computer and Its Applications.

Eugene B. Jackson, head, GM Research Staff library, before the Metal Division, Special Libraries Association, Boston, May 27; title: How the Technical Writer Can Aid the Librarian.

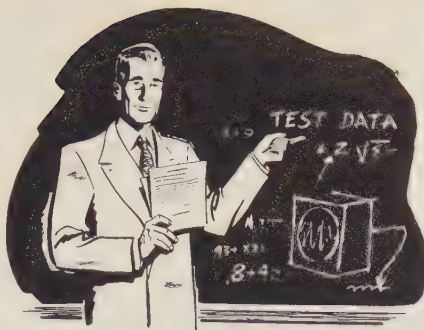
Alan S. McClimon, manager, Sales Department, Euclid Division, before the Engineer Officer Training School, Australian Army, Training Base, Sydney, Australia, June 20; title: High Performance Earthmovers Set New Standards.

Carl F. Schaefer, supervisor, ceramic development and control, Research Department, AC Spark Plug Division, before the Kiwanis Club, Fenton, Michigan, July 24; title: Ceramic Engineering.

Leonard E. A. Batz, section head, Design and Standards Department, AC Spark Plug Division, before the East Flint Optimist Club, May 16; the North East Flint Optimist Club, May 21; and the Flint Civitan Club, July 8; title: Rockets or Missiles? and before the Genesee County Association of School Boards, Swartz Creek, Michigan, June 25, title: Industrial Education Requirements.

## 1957 General Motors Conference for Engineering and Science Educators

The Sixth GM Conference for Engineering and Science Educators was held in Detroit July 7 through July 23, under the sponsorship of the General Motors Engineering, Process Development, and Research Staffs, located at the GM Technical Center. Twenty-one educator



guests attended as representatives of colleges and universities from nearly all areas of the United States.

Co-hosts and chairmen of the conference, designed to orient engineering and science educators on the product and production activities of General Motors, were: Charles A. Chayne, vice president in charge of Engineering Staff; Robert M. Critchfield, vice president in charge of Process Development Staff; and Lawrence R. Hafstad, vice president in charge of Research Staff. The conference was co-ordinated by Kenneth A. Meade, director, Educational Relations Section, GM Public Relations Staff.

On July 8 an introductory general session was held at the GM Technical Center. GM personnel who made presentations at this session included: Louis C. Goad, executive vice president, General Motors; William M. Collins, assistant secretary, General Motors; Charles A. Chayne; Robert M. Critchfield; George A. Jacoby, director of Personnel Relations, GM Central Office; and David F. Waggoner, director of Salaried Personnel Placement, GM Central Office.

From July 9 through July 12 the edu-

cators were guests of the Research, Engineering, Process Development, and Styling Staffs respectively. Host for the Research Staff program on July 9 was Lawrence R. Hafstad, vice president in charge of Research Staff. John M. Campbell, scientific director, acted as the program chairman. Research Staff speakers participating in the program included Richard C. Drutowski, supervisor of friction research, Mechanical Development Department; John S. Collman, assistant head, Gas Turbines Department; and Richard E. Marburger, research physicist, Physics and Instrumentation Department.

Charles A. Chayne, vice president in charge of Engineering Staff acted as host for the July 10 Engineering Staff program. Speakers included Maurice A. Thorne, engineer-in-charge, Vehicle Development Group; Von D. Polhemus, engineer-in-charge, Structure and Suspension Development Group; John Dolza, engineer-in-charge, Power Development Group (now retired) and Oliver K. Kelley, engineer-in-charge, Transmission Development Section (now chief engineer, Buick Motor Division).

On July 11 Robert M. Critchfield, vice president in charge of Process Development Staff acted as host for the educator group. Program speakers included John Q. Holmes, director, Production Engineering Section; Robert D. McLandress, director, Work Standards and Methods Engineering Section and Harry D. Hall, director, Process Development Section. Activities of the Process Development Section were de-



One day of the Sixth GM Conference for Engineering and Science Educators was devoted to a tour of the GM Proving Ground at Milford, Michigan. There the educators were shown demonstrations of various engineering equipment and instrumentation used in Proving Ground test work. At one point in their tour the educators saw a demonstration of a recent GM Proving Ground

development—the "road coefficient of friction trailer" (above). Mounted on the bed of the pick-up truck are water tanks. When the operator in the truck turns a switch, water is squirted under the trailer wheels. At the same time, the trailer brakes are locked. As the trailer wheels skid, the coefficient of friction of the road surface is registered instantly on a dial mounted in the cab of the truck.

scribed by **George R. Squibb**, chief project engineer, Engineering Design; **Robert B. Colten**, staff engineer, Electronics; **Clarence G. Chambers**, staff engineer, Chemistry-Metallurgy Plating; **Louis J. Pedicini**, staff engineer, Foundry; and **Frank H. Williams**, supervisor, Plant Contact and Technical Service.

**Harley J. Earl**, vice president in charge of Styling Staff acted as host for the July 12 Styling Staff program. Speakers included **Claude McCammon, Jr.**, supervisor, Public Relations and Communications; **George T. Christiansen**, executive-in-charge, Administration and Industrial Relations; **Robert F. McLean**, executive-in-charge, Product Analysis and Planning; and **Peter Kyropoulos**, executive-in-charge of technical development.

On July 13 the educators visited the General Motors Proving Ground. **Louis C. Lundstrom**, director, GM Proving Ground, acted as host. Proving Ground personnel who made presentations included **David C. Apps**, head, Noise and Vibration Laboratory; **G. A. Stonex**, head, Engineering Test Department; **A. H. Kelly**, assistant head, Mechanical Engineering Department; and **R. O. Painter**, assistant head, Electrical Engineering Department.

The educators visited General Motors Institute, Flint, on July 15. **Guy R. Cowing**, president, General Motors Institute, acted as host and **Harold M. Dent**, administrative chairman, Cooperative Engineering Program, was moderator for the discussion period. Speakers included **John F. Gordon**, vice president and group executive, General Motors and Chairman of the Board of Regents, G.M.I.; **E. K. Harris**, chairman, Product Engineering Department; **Steve Cenko**, Mechanical Engineering Laboratory; and **William F. Edington**, head, Psychology Section.

The educators spent July 16 through July 19 on field assignments at General Motors Divisions, where they observed Divisional operations.

The educators met for the closing general session of the Conference at the GM Technical Center on July 23 to sum up and present their observations to their hosts. **Anthony G. DeLorenzo**, vice president in charge of Public Relations Staff, addressed the educators in the afternoon. Dean **William L. Everitt**, College of Engineering, University of Illinois, presented "Current Problems in Engineering Education" followed by a discussion period and the conference adjournment.

## Contributors to Oct.-Nov.-Dec. 1957 Issue of

### GENERAL MOTORS ENGINEERING JOURNAL



**ROY F.  
KNUDSEN,**

contributor of "A Discussion of Present Day Dynamometers: Their Application, Operation, and Control," is a senior research engineer with the Instrument Section of the Technical Facilities and Services Department of the General Motors Research Staff, located at the GM Technical Center. Mr. Knudsen joined the Research Staff in 1954 as a research engineer. He assumed his present position in 1956.

As a senior research engineer, Mr. Knudsen currently is in charge of the application engineering group of the Instrument Section. He is responsible for dynamometer application and dynamic measurements. One of his recent projects was the development of an electronic method for simulating the inertia of a car on a chassis dynamometer.

Prior to joining General Motors, Mr. Knudsen was associated with the Simplex Valve and Meter Company as a designer and draftsman and with the Minneapolis Honeywell Regulator Company as a sales engineer.

Mr. Knudsen saw service with the Army Air Force during World War II as a communications officer. After separation from the service, with the rank of captain, Mr. Knudsen entered Swarthmore College and graduated in 1949 with a B.S. degree in electrical engineering.

Mr. Knudsen is a member of Sigma Tau, the American Institute of Electrical Engineers, the Engineering Society of

Detroit, and the Instrument Society of America. He is currently president of the latter Society's Detroit chapter. Mr. Knudsen also is a registered professional engineer in the state of Michigan.

**ROBERT W.  
LEWIS,**



who prepared the problem "Determine the Horizontal and Vertical Deflection of a Circular Beam" and the solution appearing in this issue, is a project engineer in the Engineering Department of the Aircraft

Engines Operations at Allison Division, Indianapolis, Indiana. Mr. Lewis is concerned principally with stress analysis problems in the design of axial flow power sections for turbo-prop engines.

Mr. Lewis joined Allison in July 1954 after completion of requirements for the M.S. degree at Iowa State College, Ames, Iowa. While engaged in his graduate studies at Iowa State College, Mr. Lewis served as a research assistant for the Department of Aeronautical Engineering and the Institute for Atomic Research. His thesis subject was the tensile properties of metals in the inelastic range of stress.

Before joining Allison Mr. Lewis was employed by the McDonnell Aircraft Corporation, St. Louis, Missouri, where his work was devoted to the design and stress analysis of high speed aircraft wing structure with emphasis on thick skin analysis.

Mr. Lewis was awarded the B.S.M.E. degree in 1950 by the University of Missouri, Columbia, Missouri. His tech-

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nical society affiliations include membership in the Institute of the Aeronautical Sciences.

#### DONALD P. MARQUIS,

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Mr. Marquis has been engaged in automotive engineering for over 20 years. Although he began as a metallurgist, most of his career has been associated with the design and development of chassis parts, such as steering linkages and suspension components.

Mr. Marquis joined Saginaw Steering Gear in 1953 as staff engineer. He assumed his present position a short time later. Mr. Marquis supervises product engineering of manual steering gears, steering linkages, gear shift mechanisms, front and rear suspension parts, universal joints, and automotive propeller shafts. Prior to joining General Motors, he was engaged in the engineering of similar automotive chassis products with Thompson Products, Incorporated.

Wayne State University granted Mr. Marquis the degree of Bachelor of Science in chemical engineering in 1934 and the Master of Science degree in 1939. He is a member of the Society of Automotive Engineers and the American Society for Metals. Two patents have resulted from his work in the field of automotive steering linkages.

#### JOHN T. MARVIN,

contributor of "The Importance of Complete Disclosures for Chemical Inventions," and coordinator of this issue's "Notes About Inventions and Inventors," is a patent attorney in the Dayton Office of the Patent Section. This office is one of the three principal locations of patent

activities in General Motors. The other offices are located in Washington, D. C. and Detroit. Mr. Marvin's duties involve the handling of patent applications, infringements, copyrights, trade-mark matters, and licensing agreements. His work is concerned primarily with the Delco-Remy, Inland Manufacturing, and Moraine Products Divisions of GM.

Mr. Marvin was granted a Bachelor of Science degree from Case Institute of Technology in 1929 and, in 1935, received a degree in chemical engineering from the same institution. He also has done graduate work at Western Reserve University and Franklin College.

Prior to joining the General Motors Patent Section in 1937, Mr. Marvin was chief engineer of the Cleveland Heater Company, Cleveland, Ohio.

Mr. Marvin is a member of Alpha Chi Sigma, honorary chemistry fraternity, the Engineers Club of Dayton, the Dayton Patent Law Association, and is a Registered Professional Engineer in Ohio.

Mr. Marvin's work has resulted in the grant of 45 patents in the gas appliance, metallurgy, and automotive fields.

#### WILLIAM E. MENZIES,

contributor of "Electrical Engineers Develop a New Concept for Multi-Path Direct Current Armature Windings," is head of the Direct Current Section of Delco Products Division, Dayton, Ohio. He began his

career with General Motors in 1938 as a project engineer for Delco Products.

Recently, Mr. Menzies was instrumental in developing a means of extending greatly the voltage range over which generators are stable. The machine is being made available to industry.

During World War II Mr. Menzies was responsible for the development of light weight, aircraft starter-generators, tank starter-generators, and light weight

Contributors' backgrounds vary greatly in detail but each has achieved a technical responsibility in the field in which he writes.

naval generators. During World War I Mr. Menzies, as a civilian, helped to devise a submarine detector.

Mr. Menzies has had several electrical and mechanical patents granted in his name, and he is the author of several papers published by the American Institute of Electrical Engineers.

Mr. Menzies received a bachelor of science degree, with a major in electrical engineering, from Pennsylvania State University in 1917. In 1922 the University awarded Mr. Menzies the degree of electrical engineer.

Mr. Menzies attended the Westinghouse Design School and was awarded a diploma in electrical engineering in 1918. He was with Westinghouse for 10 years.

#### PHILIP WEST,

co-contributor of the problem "Determine the Design Specifications for a Crank and Connecting Rod Transfer Mechanism" and the solution appearing in this issue, is a project engineer in the Process

Development Section of the General Motors Process Development Staff, located at the GM Technical Center.

Mr. West joined General Motors in 1945 as a General Motors Institute co-op student sponsored by AC Spark Plug Division. He graduated from G.M.I. in 1949 with a Bachelor of Industrial Engineering degree. After receiving his B.I.E. degree he left AC Spark Plug and returned to G.M.I. to enter the Dealer Cooperative Training Program. Upon completion of this program he worked for a Buick dealership until 1954, when he joined the Process Development Staff as a junior engineer. He assumed his present position in 1956.

Mr. West's work as a project engineer, in the Engineering Design Department of the Process Development Section, concerns project studies involving processing analysis and automatic machining and assembly machine development.

The technical affiliations of Mr. West include the American Society of Tool Engineers. He also is a member of Phi Eta Sigma and Alpha Tau Iota, honorary societies. During World War II he served with the U.S. Navy.

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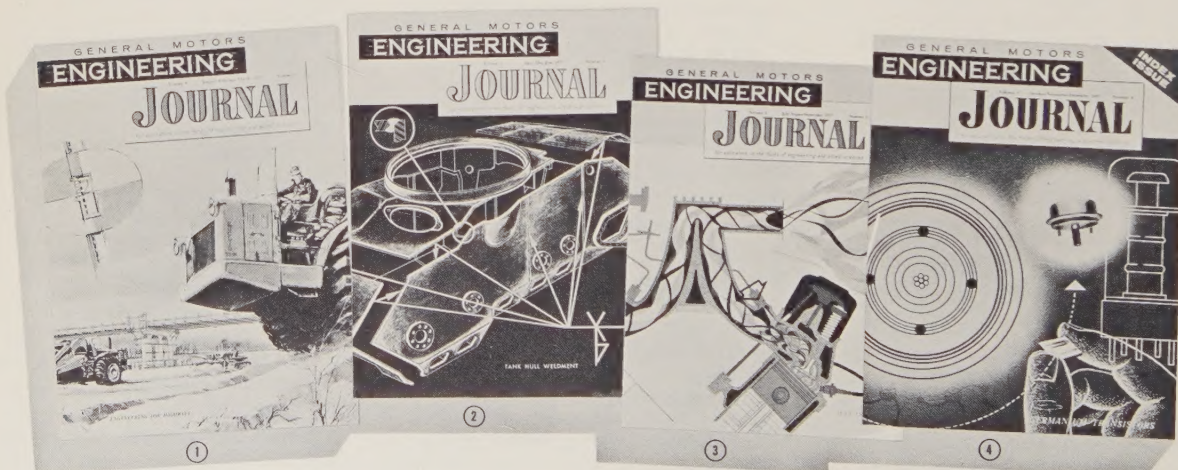
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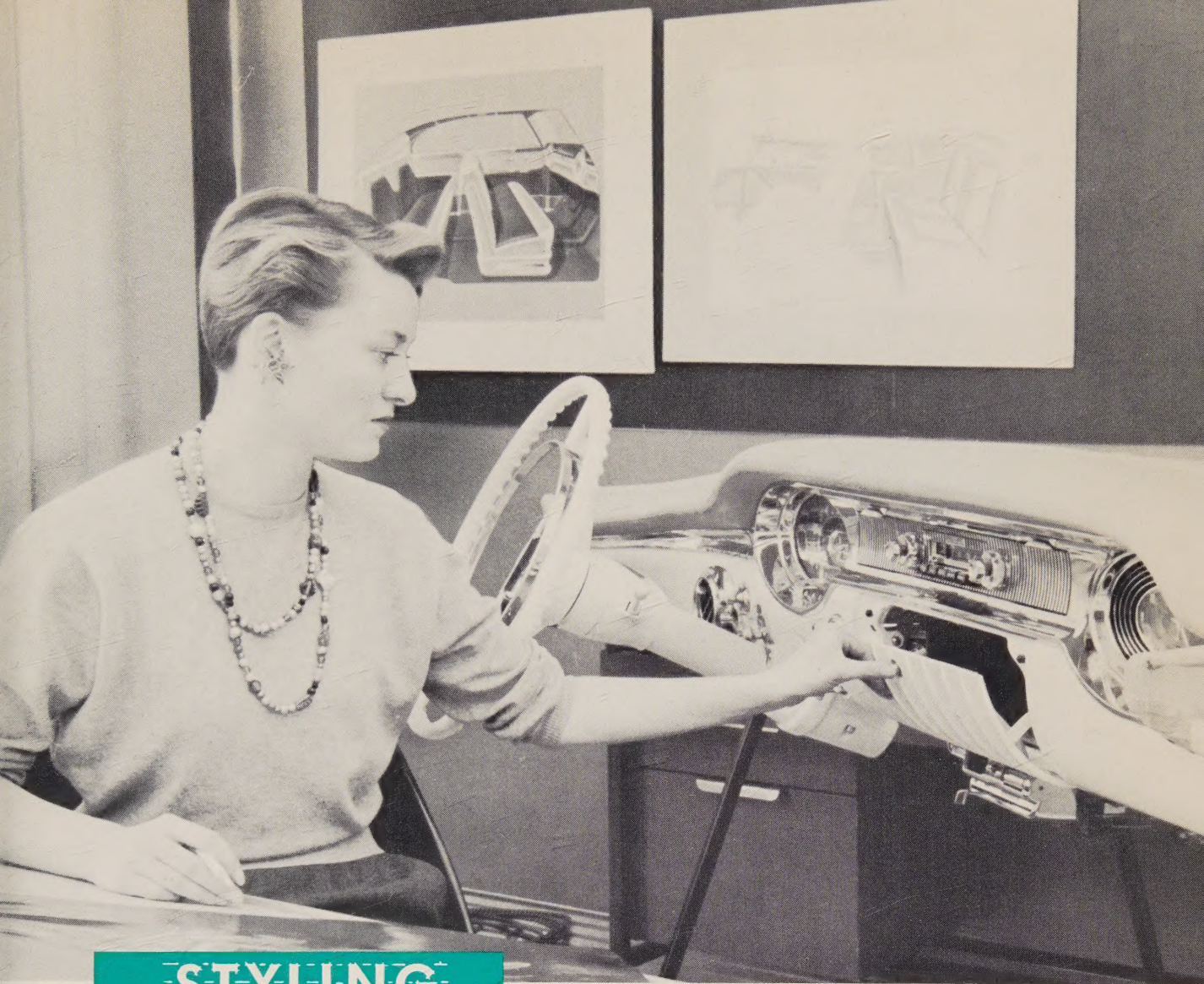
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## STYLING

### ASSIGNMENT IN GM

Women's influence upon automobiles today is marked by the fact that more of them are drivers than ever before and, when it comes to the purchase of a car, they cast the deciding vote in seven out of ten cases. In General Motors, women are helping in the design of automobiles, too.

Women designers have been employed at General Motors Styling since 1943 and today there is a woman designer assigned to each studio of the five GM car divisions as well as to other studios concerned with Frigidaire appliances and product exhibits. Their combination of styling skill and feminine point of view is valuable in the overall job of creating cars and appliances with the woman in mind. Besides being color and fabric specialists, the women designers are tuned specially to the woman driver's problems. They have been strong advocates of the six-way seat for greater comfort and visibility. They

have designed windshield wiper knobs and other dashboard controls which are easier to find at night.

Harley Earl, GM Vice President in Charge of Styling, credits women with inspiring increased beauty in car interiors, for the rapid growth of power accessories, and for today's tasteful and eye-appealing colors.

One of the women designers at GM Styling is Peggy Sauer of the Oldsmobile studio. A typical assignment is assisting in the design of instrument panels. She also works on the design of other interior features of the car such as seats, fabrics, carpets, colors, steering wheels, and door handles and knobs. Miss Sauer graduated from Cranbrook Academy of Art in 1950 with a Bachelor of Fine Arts degree. Before joining General Motors Styling in 1955, she had experience as a display designer for several large department stores.

GENERAL MOTORS ENGINEERING JOURNAL

